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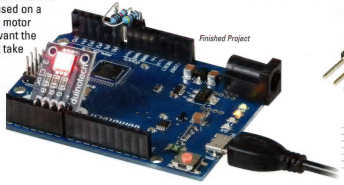
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Publisher & Editor-in-Chief
Leo Simpson, B.Bus., FAICD

Editor
Nicholas Vinen

Technical Editor
John Clarke, B.E.(Elec.)

Technical Staff
Ross Tester
Jim Rowe, B.A., B.Sc
Bao Smith, B.Sc

Photography
Ross Tester

Reader Services
Ann Morris

Advertising Enquiries
Glyn Smith
Phone (02) 9939 3295
Mobile 0431 792 293
glyn@siliconchip.com.au

Regular Contributors
Brendan Akhurst
David Maddison B.App.Sc. (Hons 1), PhD, Grad.Dip.Entr.Innov.
Kevin Poulter
Dave Thompson

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Editorial office:
Unit 1 (up ramp), 234 Harbord Rd, Brookvale, NSW 2100.

Postal address: PO Box 139, Collaroy Beach, NSW 2097.

Phone (02) 9939 3295.

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Publisher's Letter

Cutting-edge technology – in 1958

These days the pace of technology change is so rapid and so all-pervasive that most people would have forgotten that this rapid change started to happen more than 60 years ago with the introduction of transistor radios, mostly made in Japan. Before that, all radios were valve-based and many western countries had their own electronics industries, largely devoted to the manufacture of valve radio and television sets.

In a little more than a decade or so, Japan changed all that. In fact, Japan basically obliterated the domestic electronics manufacturing industry in most western countries. Nowadays many people worry about the loss of jobs to Asian countries but it all started with Japan. Not only were labour costs far lower in Japan than in western countries but the Japanese were leading the way with new technology.

That fact is highlighted by Ian Batty's story on the Sony TR-712 7-transistor mantel radio in this month's Vintage Radio pages. This set was introduced in 1958 and it had only been in 1954 when the first transistor radio appeared (see SILICON CHIP, April 2013). Those first transistor radios were largely novelty items and their main attraction was just how small they were – you could stick them in your shirt pocket.

In all other respects, those early "trannies" were woeful. They sounded awful, as anyone who can remember their "squark, squark" reproduction will attest, and their RF performance left a great deal to be desired. Their battery consumption was also very poor and for two particular reasons. First, as the battery voltage dropped, the bias in the class-B output stage became less and less optimum and severe (very severe) crossover distortion was the result.

Second, once the battery voltage dropped by more than about a third, the local oscillator would fail to work and therefore the radio itself was out of action. But while the technical fraternity might have sneered at their shortcomings, preferring the much better sound of valve radios, the man in the street was greatly intrigued and "trannies" became exceedingly popular.

And then Sony brought out the TR-712. This set was far ahead of any transistor radio previously on the market. This clearly showed that Sony was the absolute leader in transistor technology. Not only did it use a mixture of NPN and PNP transistors where previous transistor radios had been PNP Germanium types, but it also used new circuit techniques; neutralisation in particular.

Actually, neutralisation was not new and had been used in valve sets for years but this was the first time that it was used in a transistor set. To explain, early transistors had very poor RF gain and NPN transistors were generally much worse than PNP types. Neutralisation is essentially a positive feedback arrangement which gives a boost to the high frequency gain.

It demonstrated that the Japanese were making giant strides with this new technology and the resulting performance of the TR-712 was way ahead of anything that had been seen before. It must have really made engineers in western countries sit up and take notice. But from that point on, they never really caught up, in spite of the introduction of silicon epitaxial transistors and so on.

Whether it was TV sets or domestic hifi equipment, Japanese manufacturers completely dominated the market in Australia and virtually everywhere else except in the iron-curtain countries where severe import restrictions were enforced. Then the Whitlam Labor government administered the coup-de-grace to the Australian electronics industry with its across the board tariff cut of 25% in 1973 and then it was virtually finished.

Funnily enough, there is still quite a lot of specialised electronics manufacturing still going on in Australia and Japan is now merely a small part of the huge Asian phenomenon.

Leo Simpson

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Car radios emphasise AM selectivity over sensitivity

In Ask SILICON CHIP, November 2016 (page 100), T. G., noted poor AM radio reception in his/her car. This is something that I have been explaining to customers of "high end" cars for years.

The radios are manufactured for European and/or North American markets where there are a large number of competing stations in the cities. The radios are therefore built with high selectivity, ie, the ability to give clear radio reception even with nearby competing stations.

However, this means that sensitivity (the ability to get long-range reception) is being sacrificed, which is what we require in Australia. Radios that have both high selectivity and high sensitivity are more expensive and the "bean counters" do not want to supply a small market like Australia with expensive radios.

My Australian made Ferris push-button AM only radio (VB Commodore) would easily give great reception of Sydney ABC 702 until leaving Tamworth. Nothing that I have found on the market these days will even come close.

Lee Bourgeois,
Mittagong, NSW.

Why not use DC extensively for power distribution

I have to say something on this topic, with all the stories that systems disconnect because they can't synchronise when there are drop-outs, blaming renewable sources.

Firstly, years ago it was all done with three light globes; everything was mechanical and it was done manually. The question of why we can't maintain synchronisation with all the sophisticated inverters and equipment we have today mystifies me.

If we used DC transmission, there would be no synchronisation problems and transmission line losses would be greatly reduced as transformers would no longer be required. We now have means to convert voltages using solid-state devices. We already use DC for under-water transmission.

AC transmission needs more wires and thicker wires using multi-stranding to lower skin effect on top of capacitive inductance losses. Solar panels already put out DC while many wind generators have DC going into an inverter; their output could be left as DC.

Most items in homes run off DC these days (DC is safer than AC regarding electrical shocks as you need a higher voltage since the capacitance

SILICON CHIP Editorials are off-topic and wrong

I buy SILICON CHIP for its technical content, including the projects, the Ask SILICON CHIP section and occasional informative scientific articles such as Ross Tester's on radio astronomy in the January 2017 issue.

I do not want to be confronted by bizarre rants by the Publisher and Mailbag contributors against climate change and renewable energy or in favour of nuclear power.

I have formed my own opinions on these and other issues and do not want these dismissed as ignorant and wrong. I find this extremely insulting. I also trust scientific consensus regarding climate change, not someone with an axe to grind and a convenient soap box.

The January issue is a case in point as it contains two more rants by the Publisher that have no place in an electronics magazine, one criticising renewable energy and one warning about the danger that airbags could kill your daughter. What legitimate business has an electronics magazine got in weighing into these subjects? They are personal opinions delivered in the guise of an editorial.

Each issue of SILICON CHIP reminds me of those door-knocking evangelists who insisted that their beliefs were correct and that mine were wrong.

Consider that the entire electronics industry has been created by scientists and researchers. You are pleased to publish a magazine that profits from this huge volume of work, yet you belittle the scientists who have produced unequivocal evidence of human effects on climate.

Your rebuttal of Rob Fincher's considered letter in the January issue with the words "Moreover not all people are convinced that CO_2 emissions should be reduced or even that it is leading to any significant degree of global warming.

And even if that were the case, there are significant benefits of a slightly warmer climate in temperate countries" shows a breathtaking degree of wilful ignorance of the facts!

Ian Paterson,
Fullarton, SA.

Comment: there is quite a lot of information on the internet about satellite surveys showing considerable increases in global vegetation cover over the last few decades while the atmospheric concentration of CO_2 has increased markedly.

Surely that is one indication that increased CO_2 and possible global warming does have desirable effects?

See ***http://earthobservatory.nasa.gov/Features/GlobalGarden/***

And should not a technical magazine draw attention to very unsafe behaviour by people who are unaware of the potential dangers of airbags? Our feature on airbags in the November 2016 issue clearly demonstrates that airbags are explosive devices which are potentially very dangerous.

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Mailbag: continued

Closing Hazelwood may have unintended consequences

Apart from the threat to the stability and cost of Australia's electricity supply, another unforeseen consequence of closing the coal-fired Hazelwood Power Station in Victoria will be the death of, or less favourable living conditions, for the fish in the cooling pond.

It has been deliberately stocked with barramundi and also contains other fish due to its warm water and people can go and fish there.

I'm not a fisher but here someone writes about exotic fish in Hazelwood pondage: http://siliconchip.com.au/l/aaby

Here someone swims in the pondage: https://youtu.be/wopMdkoqV8M

Barramundi at Hazelwood: http://siliconchip.com.au/l/aabz

All this will go when they shut down the power station unless they can use windmills to drive electric heaters to heat the water – that would be about the only appropriate use for them. I would like to go there to swim and camp before it is closed down.

Dr David Maddison,
Toorak, Vic.

of the body does not come into play).

Each house could have the DC voltage lowered to suit the appliances and lighting would be no problem as you could set up LEDs in series to suit the voltage, as they do already.

On top of this, each house could have batteries so no black-out problems occur. Regarding batteries, an old timer from 100 years ago has resurfaced and may be the answer to the battery problem.

Edison cells using nickel-iron plates have been found in old barns etc, and are still in working order today. These cells can be totally or partially discharged and left that way for as long as you like. It does not harm them as it does other battery types. They can also be charged to high a voltage without harm. These cells would be ideal for solar and wind storage.

It would be interesting to see other readers' comments on these topics.

David T. Francis,
Sydney, NSW.

Editor's note: while solid-state DC/DC converters now commonplace, we're not sure that their reliability is anywhere near as good as that of the tried-and-true transformer.

It is already apparent that typical domestic grid-tied inverters often do fail after just a few years.

A DC grid would involve tens of thousands, if not millions, of DC/DC converters and they would have to be impeccably engineered and built to avoid constant failures and the resulting expensive maintenance and downtime.

Regenerative braking for ride-on locomotive

I am writing in connection with a question raised by one of your correspondents under the heading "24V DC Motor speed controller wanted" in Ask SILICON CHIP, on page 99 of the January issue.

I note that in your reply, you recommended the 60V/40A Motor Speed Controller on page 36 of the same issue. That controller is an excellent design for use as a general purpose controller. However, I am not sure that it would be suitable for your correspondent's needs.

The reason is that for the kind of application that your correspondent has in mind, it is most important that a controller incorporates automatic regenerative braking. Otherwise, riders are at risk of ending up in collisions, with serious consequences.

The controller mentioned above does not appear to be designed with automatic regenerative braking in mind. Its switching frequency, in the range of 100Hz to 1kHz, is far too low for controlled automatic regenerative braking to be effective.

It is possible, of course, to obtain emergency regenerative braking with this controller by closing a switch directly across the motor. But from my experience this is not the best way to stop a vehicle intended to be ridden by human passengers.

There are several points that I think need to be made:

- For ride-on applications, such as miniature trains, automatic regenerative braking is absolutely essential. Equally importantly, it works for emergency braking just as well as for normal braking.
- Emergency regenerative braking is precisely what it says. It is not the same as normal regenerative braking.
- Emergency regenerative braking is far too abrupt when one wants to make a smooth stop at the end of a trip and is completely useless for controlling one's speed when going down a grade.
- Emergency braking is terribly wasteful of energy because the energy is dissipated as waste heat, whereas in controlled regenerative braking, the braking energy is conserved by being fed back into the battery.

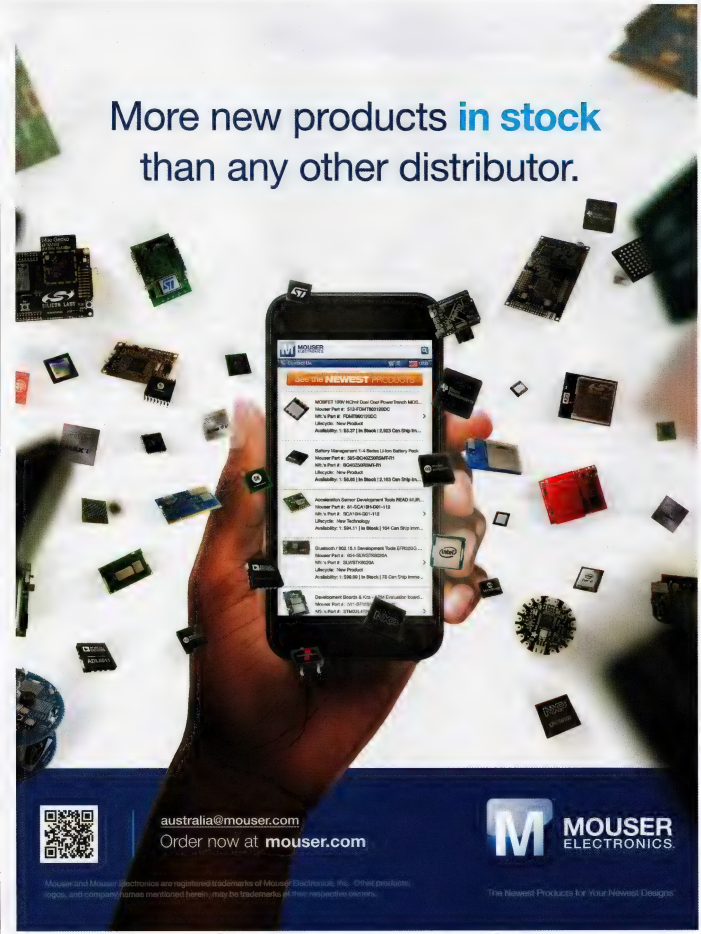
I would therefore strongly recommend that, unless your correspondent is experienced in designing motor controllers for this, he or she should consider purchasing a commercial controller specifically designed for their needs. Or, failing that, use a commercial controller designed for a mobility scooter or electric wheelchair.

Alternatively, your correspondent might consider using a controller for an electric bike. These are available on eBay, some for less than $50. I am not familiar with these controllers and the fact that many of them are so cheap makes me suspicious.

If these have controlled regenerative braking, then well and good. In that case your correspondent may save some money by buying one of these. Otherwise, I would recommend that your correspondent stay clear of them.

Prices for mobility scooter and electric chair controllers are usually much higher than for electric bikes. However the fact that controllers for mobility scooters and electric chairs are specifically designed with safety in mind is an important consideration for your correspondent to bear in mind.

Controllers for mobility scooters for sale on eBay are typically priced from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Mailbag: continued

Comprehensive solution for killing mosquitos

Regarding the letter published in Mailbag for the January 2017 issue, on page 4, David Kitson should have a look at the Mosquito Slayer.

A web search reveals plenty of information on this product. I've been experimenting with adaptation of existing cheap electrified grid traps, none of which are any use because they do not attract the mosquitos. If they appear to kill mosquitos, it's only a paltry few that are attracted to the warmth of the light; they miss the majority.

The Mosquito Slayer might be the one device that covers a majority of bases. Adding the tone generator would obviously improve it.

He should also consider octenol. The Mosquito Slayer company sell refills of the chemical and Bunnings sell a sachet called Mozzie Attract. Warming a sachet of this chemical and placing it behind an electrified grid might be worth looking into.

One idea I've never seen in practice is that of creating a small artificial closed area of stagnant water with entry through an electrified grid. In Alice Springs, stagnant water gets out of control after rain and once the grass takes off, the council cannot get it under control for months. We are currently suffering from an overpowering mosquito fleet after the December 2016 rains.

Donald D'Abrera,
Alice Springs, NT.

about $200 upwards. I hope this will be of some help.

Herman Nacinovich,
Gulgong, NSW.

Comment: While we agree that regenerative braking would be desirable for a ride-on locomotive, the correspondent has not requested that feature. Indeed, the controllers typically used for these locos are generally quite crude and do not include any sort of braking.

Some locos of this gauge are powered by small petrol motors and again, any braking will be rudimentary and mainly provided by the gearbox (similar to "engine braking" in cars).

Thinking about the braking in more detail, typical model locomotives and electric wheelchairs mainly rely on the high gearing of the motor, in conjunction with the low source impedance of the speed controller to provide effective braking (another form of engine braking).

If regeneration were to be a feature, there would need to be some arrangement whereby the motor produces a higher voltage when acting as a generator to charge the battery.

That is not really possible with a permanent magnet motor which has a fixed field strength, although one possibility would be to have the permanent magnet motor drive a boost converter to provide regeneration but that would be a major increase in circuit complexity.

Regenerative braking is possible when you have a shunt-wound or compound motor where you can arrange for separate DC field excitation (ie, increased field strength) and in that case, the motor is said to be capable of 4-quadrant operation.

Electric bikes do feature regenerative braking but in those cases their motors are effectively 3-phase brushless DC types with a complex H-bridge drive circuit. This can be put into inverting mode to provide regenerative braking.

Wind turbines don't affect grid frequency

I have just read Neil Biggar's contribution to the Mailbag section in the December 2016 issue. I agree with him about the order of events in the recent South Australia blackout. In fact, I remember when it was first reported on ABC radio and that was the sequence of events they reported, ie, the transmission system failed and then the generation system tripped out.

It was only after some politicians twisted the facts, and some media outlets reported it without checking the facts, that the public were misinformed.

I also need to comment on the statement that "It is also clear that there were no significant frequency changes (due to wind turbines) which could have caused the interconnection to disconnect."

I understand that wind turbine farms these days are AC turbines and the output is then converted to DC and then back to AC to feed to the grid. This enables the turbines to run at maximum efficiency at all workable wind speeds. The supplied frequency to the grid has nothing to do with wind speed.

In the same Mailbag section, Paul Miskelly refers to "non-synchronous generation, such as wind farms and solar PV equipment". There are AC to AC systems but they do have limitations.

Can you commission an article about how wind power is delivered to the grid here in Australia?

You have done similar great articles, including the submarine article in the December 2016 edition, and many many years ago power transmission in electric railways and another on hydro-electric systems.

Tom George,
Ballarat, Victoria.

Australia doesn't need nuclear subs

Before I start, I promise to not get nasty or cancel my subscription if anyone disagrees with my letter's contents. I quite enjoyed the technical article about nuclear submarines in the December 2016 issue but my question is, why do we really need nuclear submarines at all? There are advantages and disadvantages, as stated in the article but in my opinion, it is all a bit of a storm in a teacup.

It really comes down to whether Australia needs offensive submarine capability or just offensive capability; there is a difference.

Nuclear submarines are really a "don't mess with us – look what we have" type of weapons system, designed primarily for attack or pre-emptive strike. Yes, they can do other things like covert operations and fleet defence but they are typically for taking the fight to the enemy and to be used as a deterrent.

Offensive capability is all about being able to do those things if required and also being able to support our allies in their operations.

Australian submarines are mainly for

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Snoring could be a sign of something more serious

I read the Serviceman's article on his anti-snoring device with interest and I agree that it is a clever solution but I think it only solves part of the problem which is far more serious.

I have suffered from Sleep Apnoea for about ten years now which is often the cause of the snoring in the first place.

While the noise from the snoring is bothersome to most, the bigger problem is that the person is usually snoring because their brain and body is not getting enough oxygen and also their carbon dioxide levels are rising.

This happens because their airway becomes blocked as they sleep and the snoring is the body's way of getting the oxygen it needs. This is basically what Sleep Apnoea actually is.

The serious part of the problem comes about because the reduced oxygen levels and increased carbon dioxide levels actually means that the body's cells begin to die when the person is asleep which is obviously bad.

Also the person often is not actually getting the rest they need because even though they appear to be asleep, when a sleep test is done it becomes obvious that they are not getting the deep restful sleep that their body needs.

It has been estimated that Sleep Apnoea left untreated will reduce a person's life by several years. When I was tested, the technician asked me how many times I woke up overnight and I said three or four times, but they said the computer measured me waking more than 50 times per hour! How can you get a good sleep like that?

There are several "solutions" on the market to treat Sleep Apnoea but the one that works for me is the use of a CPAP machine. CPAP stands for Constant Positive Airway Pressure, and is a fancy way of saying that you sleep with an air pump keeping you breathing properly all night.

I noticed a significant difference when I woke up after using a CPAP the first day and I didn't snore at all afterwards. I now sleep all the time with a CPAP and while it took me about a week to get used to the mask I wear at night, it isn't a big deal really.

My advice to the readers is that if you snore at night, it may be more than an annoying noise so simply go to your doctor and arrange to get checked.

It takes two nights, one to get checked and one to get the data required to set up the CPAP if you need one. If you do need a CPAP then just get one and be done with it, you will be surprised at the difference it makes and you will live longer and sleep much better.

Andrew Pullin,
Wodonga, Vic.

coastal patrol and defence, not attack. Can they attack if required? Of course they can and they are very effective at it. There have been a few occasions where Australian submarines have gone where angels fear to tread in exercises and taken out high-value targets.

So on the occasion where an Australian submarine "sank" the American aircraft carrier (flagship) in an exercise, I think our "woeful" Collins Class subs proved themselves. Collins subs can do covert operations like inserting Special Operations teams, they can do littoral (coastal) surveillance of enemy territory and they could do offensive patrols and sink convoys if required.

Nuclear submarines are designed for long patrols far away from base but for coastal patrols you don't actually need that. A Collins-class boat can patrol for weeks, which is more than enough time, and they certainly have more range and capability than WWII submarines and they seem to do a good job.

In regards to weapons systems, Collins submarines are able to fire torpedoes and were supposed to be able to fire missiles from their tubes; it was one of the arguments for getting rid of the F-111 fighter/bomber aircraft that the submarines could take over long-range strike capability. Any new submarines would also need to have similar weapons system capabilities.

I also don't see the problem with putting a diesel engine into a nuclear submarine hull. The hull itself is a proven technology. The diesel engine is a proven technology so they should be interchangeable in this case. The diesel would have less range, sure, but I have already covered the fact that the range it would have would be adequate.

Also, I don't think that people are taking into consideration the enormous advances in battery technology over the last decade or so that would mean that the range would be much greater in relative terms than today. Lastly, the modern nuclear hull with a diesel engine would probably be even quieter than the same nuclear submarine.

I don't think Australia needs to join the nuclear submarine club. I think it would cause more problems than it would solve as we would end up with the disposal problem at end of life still and our neighbours would likely ask themselves why we need such weapons and possibly begin a regional arms race that Australia can certainly not afford.

Andrew Pullin,
Wodonga, Vic.

12V fridges work well if installed properly

An entry in Serviceman's Log in the November 2016 issue ("Fuses can be deceptive") reminded me of my experience with three-way fridges. About 12 years ago, almost all caravans had 3-way fridges and used trailer plugs for connection. Almost every used van at that time had pin 2 surrounded with melted plastic. The dealers blamed the fridge!

Being electrical, I did some checking; the fridge takes about 12A but the plug was only rated at 7A with a 10A-rated cable, resulting in the overheated pin and very warm wires. I solved this by fitting a 32V 2-pin plug and 15A cable.

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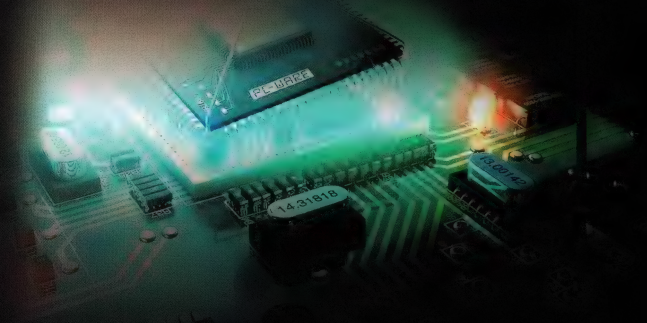

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The fridge then worked properly.

Another problem with the 3-way fridge is the chimney design at the rear.

Dealers still tell customers that the fridge will not work well on 12V but it does if the manufacturer's advice is followed, ie, deliver an actual 12V supply to the fridge when it is running and a properly proportioned rear vent; a fan does help.

We have now had two caravans with wiring that I modified to 6mm automotive cable with a properly proportioned vent at the rear of the fridge, plus a fan.

I have a 13.8V 20A power supply and have had these fridges pump down from a hot start to freezing on 35°C+ days; they do run out of performance in the tropics with 40°C+ days and hot nights. Even our Engel struggles at 45°C.

The Dometic 3-way fridge we currently have had to be re-gassed due to a pipe breaking and it now works well when travelling in the tropics (even freezes) whilst running on 12V. Our current fridge has a 12V element rated at 130W, supplied via the 35A pins on the 12-pin connector and has been OK for over seven years now (the 240VAC element is rated at 135W).

Jim Chrismas,
Gosnells, WA.

Maintain the current flow status quo

In reply to Greg Walker (Mailbag, December 2016, page 8) regarding his preference for electron flow versus conventional current flow, I am in favour of maintaining the status quo.

Consider a single line of electrons between the positive and negative poles of a DC source. The positive pole will attract the first electron which moves to the positive pole, leaving a positively charged "hole" in its place.

The second electron then moves to the positive hole left by the first electron, in turn leaving a positive hole in its place. The next electron then moves to the positive hole left by the second electron, etc.

Clearly there is movement of electrons from a negative to positive direction. But if you think about the movement of the positive holes, they are moving from the positive pole to the negative pole.

Current flow therefore may be thought of as a movement of electrons from negative to positive or a movement of holes from positive to negative. Leave things as they are – it really makes little difference to the understanding.

Terry Ives,
Penguin, Tas.

Praise for switched-capacitor DAC design

The circuit notebook entry "Precision switched capacitor DAC needs no precision components" in the November 2016 issue by Andrew Partridge is brilliant! I did some web searching to see whether the design was unique. All I could find was garbage; nothing so simply perfect, the balancing of the charge and discharge of the capacitors which also corrects for any small difference in capacitance in each stage is simple yet effective.

I would love to see a complete design for a 24-bit DAC with CD and 24bit/192kHz via TOSLINK optical and S/PDIF coaxial input based on this design.

John Cornwall,
via email.

Error in synchronous speed calculation

Thank you for publishing my letter on the role of wind power in the major blackout in South Australia last September (Mailbag, December 2016, page 10-13).

It has been pointed out to me by my friend Dennis Workman that I have made an error (and a fundamental one at that) in the letter.

I think you too might have queried the figures at some point, but in the haste to meet the publication deadline I guess I wasn't thorough enough.

Synchronous speed for a 2-pole machine (whether generator or motor) for 50Hz AC is 3000 RPM, not 1500 RPM as I stated in the letter. If a reference is required, see any electric power engineering text, but the following is the one I was able to find:

Fitzgerald A. E. & Kingsley C. (II) 1961 Electric Machinery – The Dynamics and Statics of Electromechanical Energy Conversion. Second Edition. McGraw-Hill Book Company Inc. p127, equation 3-60.

In longhand, mechanical rotational speed is 2 ÷ (number of poles) times operating frequency in cycles per minute.

So, for an operating frequency of 50Hz (or 3000 cycles per minute),

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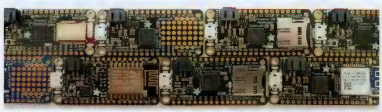

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Current flow is distinct from electron flow

I missed Greg Walker's letter about current flow in the December 2016 issue of SILICON CHIP and only became aware of it when I read the replies in the January 2017 issue. Greg seems to be labouring under the misconception that current and electron flow are one and the same thing.

While current and electron flow are often related, this is not necessarily the case as Nigel Miles indicates on page 8 of the January issue. For example, if a current is induced in a gaseous plasma, the plasma current could be caused by electrons travelling in one direction, opposite to current flow, and positive ions simultaneously travelling in the opposite direction, in the same direction as current.

In a metal arc, one would expect that positive metal ions would be a major contributor to current in the arc, flowing from positive to negative.

There are other important distinctions between current and electron flow. Current flows in a conductor at a speed determined by the speed of light in the media surrounding it, so for example the speed in a common polyethylene coax is the speed of light in polyethylene. The speed of electrons in a cable current carrying might be of the order of a million times slower.

I'm afraid I can't agree with David Francis' explanation of the arrows in semiconductor symbols. They indicate which side of the junction has the P-type material and only indicate direction of current flow in some circumstances. For photo- and zener diodes, for example, in their usual mode of operation the current flows in the opposite direction to that indicated by the arrow.

In the case of JFETs, the arrow indicates the polarity of the gate material with respect to the channel, so the arrow pointing to the channel indicates that the gate is P-type and the channel is N-type, and in normal operation the gate is usually reverse biased so leakage current flows out of the gate, opposite to the direction indicated by the arrow. The arrow indicates current flow only in circumstances where the junction is forward-biased.

And for the record, my National Semiconductor TTL data book from 1976 uses the convention that currents flowing into the device are positive and currents flowing out of it are negative. I have just downloaded the datasheet for the 74xx04 series of TTL devices from Texas, dated 1983 and updated 2004, and it uses the same convention.

What this means is that a current flowing from an output into an input would be considered negative at the output device and positive at the input device. It shouldn't really matter so long as we all understand the convention.

Phil Denniss,
Darlington, NSW.

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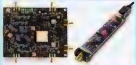

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Mailbag: continued

the mechanical rotational speed for a 2-pole machine is (2 ÷ 2) × 3000Hz = 3000 RPM. I have no doubt that any experienced power systems engineer will pick the error immediately!

Regarding islanded solar PV systems; as you have probably already deduced, the fundamental importance of the requirement for the presence of synchronous inertia on any electricity grid may provide the answer to your question, asked many months ago in a Publisher's Newsletter, as to why the solar PV units in a neighbourhood that is islanded by a fault upstream in the grid can't be permitted to continue to operate in that islanded section.

I have done a search on "Why can't an islanded section of the grid run on its embedded solar PV panels?". I didn't find anything that addressed the question directly.

There are a number of papers (not peer-reviewed) that suggested that there are unspecified challenges to sharing power derived from solar PV and/or wind on microgrids or islanded sections of the grid but they weren't particularly helpful. Here are a couple that suggested that some serious work is being done:

http://siliconchip.com.au/l/aac2
http://siliconchip.com.au/l/aac3

The second includes the description of a study of a microgrid configuration.

A quick perusal suggests that the conclusions include the interesting item that the costs of the necessary protection equipment required to make such an islanded microgrid safe are, at present, very high. So it seems that there are very real problems involved that allow islanded grid sections to operate in safety.

Paul Miskelly,
Mittagong, NSW.

Editor's comment: you are right that it would be very difficult to guarantee safety (especially to repair technicians) if islanded PV/wind generators were permitted to continue operating.

It presumably is technically possible to do so but clearly not advisable. The only realistic scenario would be if homes with PV/wind generators had an isolation switch and the generators could be permitted to run once isolated (some sort of battery storage would also be desirable).

Maybe grid synchronisation could be by electronic means

In the February issue, Kenneth Moxham commented that the major power network issue is the diminishing number of large, high inertia, rotational generators (ie, conventional power stations) to provide AC synchronisation for the multitude of small generators.

Most small generators produce DC which needs to be converted to AC synchronised with the grid before distribution.

Kenneth also said that a second large rotational generator on a grid is synchronised with the grid by a simple throttle control. He also mentioned the possibility of synchronisation to an external signal – but what signal?

We need another signal – from outside the system – which controls ALL generators, large and small. We need a signal, available across the network, providing millisecond precision and completely independent of "rotational capacity".

SILICON CHIP has presented many projects using the signals from GPS satellites to keep time to millisecond precision. I am sure that a device (based on GPS timing signals) could be constructed to control the phase of all AC generators on the grid for just a few dollars each.

It seems silly to control a major power station with a $20 controller but it would seem to solve the problem. If all generators were controlled by an external signal then all generators would be able to continue operation, even if major inter-connectors or generators were lost. Integrating more micro power generators, with their own controllers, to such a system becomes trivial.

Someone would have to make the political decision to start the national grid sine wave at zero at precisely midnight GMT (or whatever) – but it does seem to me that the technical solution is neither difficult nor expensive.

Cliff Hignett,
Naracoorte, SA. SC

Vale Maurie Findlay

AUSTRALIAN RADIO & ELECTRONICS LOSES "ROYALTY"

The passing of Maurice (Maurie) Findlay on January 21st this year at the grand old age of 88 brought to a close a major part of the "golden era" of Australian Radio and Electronics, by a man who helped shape it – and the lives of many of the people who are still involved today.

A much younger (and dare we say dapper!) Maurie Findlay graced the cover of Radio and Hobbies in June, 1949.

Like many of his era, Maurie attended night school to study electrical engineering then in 1948 started with "Radio and Hobbies" magazine, reporting to another legend, the great John Moyle.

It was during this period he wrote the "definitive" article on crystal sets, inspiring an eight-year-old boy to build his first – that young boy years later worked for Maurie Findlay and then even later started a small car radio business, which he called Dick Smith Car Radio.

After Radio and Hobbies, Maurie worked for Hawker de Havilland, stationed at the Woomera (SA) rocket range and in England, where he worked on the flight tape recording system for Black Knight and Blue Streak nuclear strike medium range ballistic missiles.

He later started Findlay Communications at Artarmon, where he designed and built several "leading edge" products:

- VHF two-way radios (fitted to the majority of Sydney's taxi fleet)
- Stingray 120 & 140 SSB radios that were used by interstate truck drivers, sailors, the School of the Air, the Royal Flying Doctor Service and anywhere else emergency two-way communication was required
- Single-channel SSB Receivers (R28) for the Australian Dept of Aviation communication bases (Dick Smith confirming several years ago that they are still in operation – after 30 years!).
- 1kW SSB Transmitters for the Dept of Aviation. Unfortunately, these were not a success and the Dept of Aviation's penalty clauses kicked in and destroyed the company.

Maurie wrote a number of articles for SILICON CHIP in the period from April 2005 to June 2012.

His only son John told SILICON CHIP that his Dad never really recovered after this setback and while he had a number of jobs, ill health plagued him, culminating in his losing both legs to diabetes. He said:

"My Dad was a tough bastard, 88 years old, type 1 diabetic, both legs amputated, living on his own and he was still working in his late 80s. I'm just grateful that he never ended up in a nursing home (thank you Dick Smith without your help he would have) and he retained his independence. I will miss him so very much, he was an inspiration to me and I hope his grandchildren will not only be proud of him and his achievements but will know that he truly loved and cared for them even though they hardly knew him.

He was 'Royalty' in the Australian electronics industry, a status that he would never have aspired to."

He is survived by his partner Sue, stepson Mark, stepdaughter Donna, son John, four grandchildren and two great-grandchildren. SC

Despite losing both legs and living on his own in Sydney's west, Maurie Findlay was active to the end, seen here working on the "Palmavox" which he wrote up in SILICON CHIP.

Simply... BRILLIANT!

By LEO SIMPSON

Philips BDM4350 4K Brilliance Monitor

Many people use two or three monitors to keep a whole range of windows open while they are working. But this takes up a lot of desk space and it can be frustrating if you "lose" the mouse while moving from screen to screen. Why not take the simple approach with a single large 4K monitor?

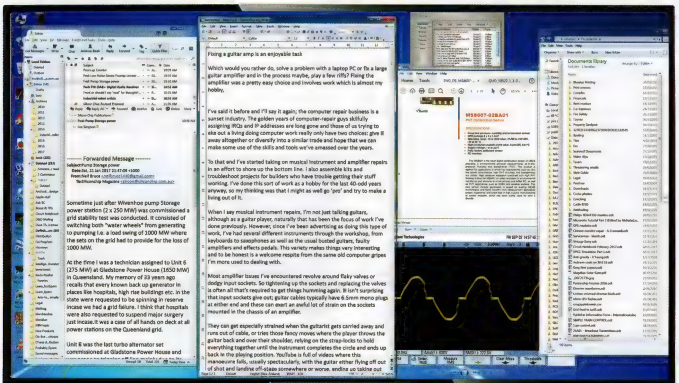
Back in September 2015, in an article entitled "4K Monitor Shoot-Out" we compared two large 4K monitors which, at that time, were the best available for the price.

The article was triggered by my using two screens to view a bunch of open windows at any one time. This is a great time-save measure so since you don't have to wait for the PC to switch between windows.

It also streamlines the process of "dragging and dropping" text or files from one application to another. In my set-up I had a 24-inch 16:10 HD monitor set up in Landscape mode while the second, a 23-inch 16:9 HD monitor, was set up in portrait mode which is good for displaying files in folders, long reports or emails.

But eventually I became sick of "losing the mouse" when moving from one screen to the other. The solution? Use a single UHD display (4K resolution). We had several 30-inch Dell 2K monitors and while they are good, I wanted something much larger, if I could get it.

I was already using an LG 32-inch smart HD TV at home with my laptop but it was only good for displaying, say, three windows at a time. Besides, it was an HD monitor and I now wanted a UHD monitor with its higher resolution which is most desirable when using a large screen.



One of the advantages of a larger screen is having room for multiple windows.

Comparing the three monitors: a 23-inch at the front, 40-inch in the middle and the Philips 43-inch at the rear.

With much larger screens, the individual pixels are much more apparent and this detracts from the overall image.

It just so happened that at that time, Aldi had a special on their "Bauhn" 42-inch 4K 16:9 monitor. I had no interest in using it for watching TV but I thought it would be a bargain at the price of around $500. I duly purchased one and set it up on my desk.

This caused Nicholas Vinen to go green with envy, as I was upstaging him with his two Dell 30-inch monitors. Naturally, he wanted to go one better but he turned up his nose at the Bauhn monitor and he found that Philips had a 40-inch 4K monitor, their model BDM4065UC which was almost exactly twice the price. He duly ordered one (at company expense!).

You can read the rest of the story in the September 2015 issue (**www.siliconchip.com.au/Issue/2015/September**).

Suffice to say that Nicholas Vinen thought that the Philips monitor was clearly superior to the Bauhn monitor and that was mainly because of its better latency, being much faster in response to mouse movements. The Philips also had a faster refresh rate of 60Hz instead of 30Hz and that is most important if you use the monitor for playing games (no, I have not seen Nicholas playing games on the monitor but you never know...)

Being a scrooge, I put up with the worse latency of the Bauhn, justifying it in that I really didn't need it to be really fast and besides, I quite liked its slightly brighter picture. (To be honest, the slow mouse response could be frustrating at times!)

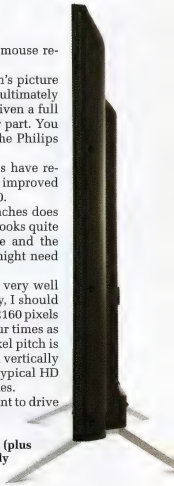
But quite a few months later, the Bauhn's picture started to become intermittently jittery and ultimately it failed completely. I was subsequently given a full refund by Aldi, with no quibbles on their part. You can guess what I did next: I purchased the Philips monitor.

Fast forward to the present and Philips have released a significantly larger monitor with improved specs. It is a 43-inch model, the BDM4350.

While a diagonal measurement of 43 inches does not sound much larger than 40 inches, it looks quite a bit larger when compared side-by-side and the screen area is actually 17% larger. You might need a larger desk.

In fact, such a large screen lends itself very well to being on a "stand-up" desk. By the way, I should mention that 4K resolution refers to 3840 x 2160 pixels (ie, about 4000 pixels wide, hence 4K), four times as many pixels as a 16:9 HD monitor. The pixel pitch is 104 PPI (pixels per inch) horizontally and vertically and this is better than the pixel pitch of typical HD monitors (1920 x 1080) of around 24 inches.

It is also important to note that if you want to drive



The BDM4350 is really thin, too: just 82mm (plus 160mm for the stand). It weighs a reasonably hefty 9.4kg.

a 4K monitor at its native (ie, highest possible) resolution and with refresh rate of 60Hz, your video card needs to drive it from a Display Port. If you are not worried about getting that refresh rate, you can use an HDMI port; preferably HDMI 2.0 but HDMI 1.4 is OK. As reported in the September 2015 issue, we used a GeForce GTX750 video card and set-up for the Philips 43-inch monitor is quite straightforward.

The Philips monitor has an IPS (in-plane switching) LCD and in this respect, its horizontal viewing angle is noticeably wider than the aforementioned 40-inch model. In fact, the viewing angle is quoted at 178°; horizontally and vertically. The LED screen illumination also appears brighter and more even across the screen; another worthwhile improvement. Brightness uniformity is quoted at 96~105%. Its brightness is quoted is 300cd/m² and contrast is 1200:1.

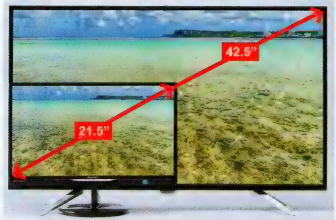
While the viewing angle for the 43-inch monitor's IPS LCD screen is much better than the 40-inch model, the contrast ratio of 1200:1 is not as good as the 40-inch monitor's figure of 5000:1 but few users are likely to notice this or be fazed by it.

As with the vast majority of large screen monitors, the sound quality is really quite mediocre. It has two built-in speakers, driven by a 7W amplifier. Yes, it can be quite loud but if you want better quality, you will have to invest in sound bar at the very least. Again, most users probably won't bother.

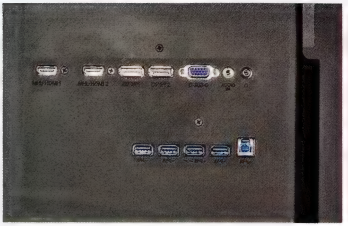
Just in case you might worry about the power consumption of such a large monitor, it really isn't a concern at around 60W in normal viewing mode. Standby power consumption is less than 500 milliwatts, dropping to zero if you use the rear-mounted power switch.

One feature I don't like is the rubbery 4-way switch to access and select the various modes. Because the switch is at the back of the monitor, you have to crook your wrist around from the front (naturally) and then somehow manipulate the rubbery toggle to move up and down the menus and then press it to select one. Surely, it doesn't have to that tricky. Of course, most users will only make changes very occasionally but when you do, you have to go through the same fiddly process.

That complaint aside, the Philips 43-inch monitor is a very satisfying unit to use. Priced at around $1000+GST, it should be high on your list if you want a high performance, large screen 4K monitor. SC



This gives a much better idea of the sheer size of the 43-inch monitor when compared to a 21-inch.



Compared to some monitors of the past, the rear panel is positively spartan: two HDMI inputs, two Display Ports, audio in, headphones plus a 4-port USB hub.

Main Specifications – Philips BDM 4350

Picture/Display
- LCD panel type: IPS
- Backlight type: W-LED system
- Panel Size: 42.51 inch (108cm diagonal)
- Effective viewing area: 953 (H) x 543 (V) mm
- Aspect ratio: 16:9
- Optimum resolution: 3840 x 2160 @ 60Hz
- Response time (typical): 5ms (Gray to Gray)
- Brightness: 30cd/m² maximum
- Contrast ratio (typical): 1200:1
- SmartContrast: 50,000,000:1
- Pixel pitch: 0.2451 x 0.2451mm
- Viewing angle: 178° (H) / 178° (V), @ C/R > 20
- Picture enhancement: SmartImage
- Display colors: Color support 1.07 billion colors (10 bits)
- Scanning Frequency: VGA/HDMI: 30 - 99kHz; DP: 30 - 160kHz (H) / VGA: 56 - 80 Hz ; HDMI/DP: 23 - 80 Hz (V)
- Mobile HD link: 1080P @ 60Hz
- Colour Space: sRGB

Connectivity
- USB: USB 3.0x4 (1 w/fast charging)
- Signal Input: VGA (Analog), DisplayPort x 2, HDMI (2.0)/MHL x 2
- Sync Input: separate sync, sync on green
- Audio (In/Out): PC audio-in, Headphone out

Power
- Eco mode: 46.5W (typical)
- On mode: 63.1W (typical) (EnergyStar 6.0 test method)
- Standby mode: <0.5 W (typical)
- Off mode: zero watts with AC switch
- Power LED indicator: Operation - White, Standby mode-White (blinking)
- Power supply: Built-in, 100-240VAC, 50-60Hz

Dimensions
- With stand (maximum height): 968 x 630 x 259mm
- Without stand: 968 x 562 x 82mm

Weight
- With stand: 9.72kg
- Without stand: 9.40kg

AUSTRALIA'S LARGEST VINTAGE RADIO EXHIBITION

HRSA RadioFest
35th Anniversary
The Golden Age of Radio

By Kevin Poulter
President, HRSA

See and hear amazing radios from the Golden Age of Radio, in April 2017.

Hundreds of Bakelite and timber radios will be on display, with some for sale and many parts available. Collectors can also purchase valves, dials, HRSA magazines, high voltage capacitors and cables.

The 35th RadioFest celebrates the 35th Anniversary of the Historical Radio Society of Australia (HRSA). Many of the over 1100 members around Australia are bringing their prized radios to display or sell.

Delight in seeing and hearing all things vintage radio

Do you like the look and sound of Bakelite or timber-radios? Highlights will include Bakelite radios in almost every conceivable design and colour, televisions, crystal sets, military radios, transistors and two-way radios (manufactured by PYE and Philips nearby in the 1960s), plus spark radios from the "Titanic" era – a tragic event that caused radio transmitters to become mandatory on all ships.

Amazing vintage radios

With an estimated 30,000 vintage radios in HRSA members' collections, visitors can expect to see the best of the best, with many radios rarely or never seen in public before. Some are the only ones in existence. The entire ballroom and surrounds of the Kingston Town Hall in Moorabbin (Melbourne, Victoria) will be filled with enthusiasts savouring the 1000+ radios and parts.

Musical masterpiece

The Kingston Town Hall features a rare Wurlitzer organ, rescued in 1967 from the State Theatre in Melbourne and once again fully operational. The organ's original arrival in Melbourne was a sensation, transported from the wharf to the theatre in twenty-seven lorries and reported as the largest in Australia. Scott Harrison, a HRSA member and leading Wurlitzer organist, will perform tunes of the era on each hour.

About the HRSA

The Society was started 35 years ago by Ray Kelly and a small group of enthusiasts who wanted to collect and preserve Australia's radio history. Some members come from a radio-related career, others have no technical knowledge, just an empathy for radio collecting. There's also a wide range of interests, like members who only collect one era, for example the 1920s, or the much later transistor sets, exclusively microphones, or military radios. Since its inception, the HRSA has endeavoured to cultivate and provide the means for members to collect radios, the parts needed for them, learn about radios, restoration and the history associated with Australia's radio heritage. A major benefit is also the cultivating of friendships.

Often members meet people they knew in radio 10, 20 or even 30 years ago, resulting in animated discussions on the old days and the subsequent years.

The HRSA valve (and parts) bank

Need hard-to-find parts? Browse through new or excellent condition vintage radio parts, radio knobs (even replica knobs made to order), dials, valves, radio magazines, books, printed posters and so much more on display and sale.

Choose from the 50,000 new or tested valves in the "Valve

This seller had a fantastic range of very early Astor Mickey radios, including in ivory Bakelite and an AWA "Empire State".

WHAT: HRSA 35th Anniversary RadioFest
WHEN: Sunday, April 9th; Public 10am – 3pm (HRSA members 7-9th April)
WHERE: Kingston City Hall, Moorabbin, Vic

Bank" run by the HRSA. Other parts available to HRSA members include high voltage capacitors, authentic design power cables and rare looms, to name a few.

Join us to admire, look and learn

Many members have a technical knowledge of radios, in fact some write about Vintage Radio in Silicon Chip magazine. So bring your questions!

Members and visitors are also eligible to win one of many retro radio prizes. If you visit early and would like to learn about joining the HRSA, there's a limited number of HRSA colour magazines available free, with a membership form.

Or to enquire about membership now, either write to the Membership Secretary, HRSA, PO Box 2283, Mt. Waverley, Vic 3149, or fill in the membership form at www.ozradios.com

Access all areas

The RadioFest is open to the public on Sunday April 9th 2017, between 10am and 3pm. Members have access over the three days and to the dinner, so consider joining the HRSA.

At only $35, including a colour magazine four times a year, access to the valve and parts bank, meetings and auctions, membership is outstanding value.

35th Member's Dinner

We are pleased to announce the guest speaker at the member's dinner will be Dick Smith, the hugely successful entepreneur and adventurer. Dick's attendance has created exceptional interest and tables are nearly sold out, so members need to book soon!

Program and event details

More information, including the program can be seen at www.ozradios.com The venue is the Kingston Town Hall (formerly the Moorabbin Town Hall), which is located near Moorabbin Airport in Melbourne's south east suburbs. The website is updated as new details are available, so return regularly for the latest information. SC

Leith Tebbit with his award-winning restored AWA console, at the last RadioFest in Melbourne. Leith's outstanding craftsmanship to make the very aged console into "as new", was featured in Silicon Chip, October 2013.

BRIGHT LED POOL LAP COUNTER

It has been more than a decade since we produced a swimming pool lap counter – and times (and available parts) have changed significantly. This all-new design should be very easy to build and uses a rather unique lap sensor!

THOSE FORTUNATE ENOUGH to swim in a 50-metre pool don't have to count very many laps in order to cover a reasonable distance.

For example, just 20 laps means that you have swum a kilometre. But even then, as you plough up and down the pool, it is pretty easy to get distracted and lose count. Some people cope with the problem by swimming five laps freestyle, five breaststroke, five backstroke and so on.

The problem is worse if you're swimming in a 25-metre pool (as many, even top-level swimmers, regularly train in) and much worse if you're swimming in your home pool, which may be only 10 or 15 metres long. For a 10-metre pool, you need to do 100 laps to cover a kilometre.

Believe us, trying to keep track of that many laps in a home pool while you swim back and forth is practically impossible. Was it 64 laps or 46?

This is where our Pool Lap Counter comes to the rescue. It will display the number of laps you have completed on a 2-digit readout, so you can let your mind wander, solve the world's problems or even compose your new symphony while you swim up and down.

The Pool Lap Counter consists of two parts. First is a small plastic box which contains the counter circuit and 2-digit readout, along with 6V of "AA" batteries to make it completely portable (and safe – you don't want a mains adaptor anywhere near the pool!).

The other part looks just like a large frozen food "brick" as would be used in a reasonable-size cooler/fridge. That could be because that's exactly what it is – we've pressed one of these into service to act as the lap sensor. But more on this anon.

Two ways of counting

The way it works is as follows. You place the sensor at the far end of the pool (ie, opposite from where you normally start). You then swim to the other end and touch the sensor, whereupon the display indicates "01". Congratulations, you have completed one lap!

When you swim up and back and touch the sensor again, the display will indicate "03".

In other words, the display increments by two each time the sensor is touched.

As an alternative, because this Pool Lap Counter uses the intelligence of a PIC microcontroller, you can start and finish your laps at the same end of the pool. In this case, it displays "0". You then swim up and back, press the sen-

A close-up of the business end of the Pool Lap Counter, as seen on the pool deck opposite. Try not to splash pool water on it!

sor and it displays "2" and so on, until you are exhausted!

A further counting option is where the Lap Counter increases by one each time the pressure plate is tapped, for example, laps around an oval running track. The counting option is set using two jumpers, JP1 and JP2.

The circuit has two inputs; either can be used for lap counting. One is for the pressure plate that's generally used with pools and the second is for a standard momentary pushbutton switch.

The display lights up each time one of these inputs is activated and stays lit for a configurable period of typically five seconds. The display is switched off after this period to extend the battery life. The display on-time can be set to be between half a second and 10 seconds or can be configured to be permanently lit if desired.

The counting rate is restricted so that the lap count does not increment more than once when the pressure plate or switch is activated. The normal delay period is five seconds but it can be reduced to as little as 40ms (ie, 25 increments per second).

This is not so useful when you're swimming or running but there may be other uses for the Lap Counter where more rapid counting is necessary, for example, if counting the number of people passing through a door by placing a pressure plate on the ground.

The current lap count can be displayed at any time by pressing the View switch. The lap count is cleared to zero by pressing the Clear switch. These two switches are located on the front panel of the Lap Counter box. A power switch is also included nearby.

The display is designed to be bright enough to be seen in daylight but there may be times when the display is too bright, for example, if you're swimming in an indoor pool or at night. As a result, we have incorporated a dimming function. The brightness can be reduced in four steps from maximum (100%) down to 25%.

Four AA cells (6V) power the counter. To obtain a reasonable battery life, the 7-segment displays are lit for just five seconds each time the button is pressed.

Of course, the ICs are powered while the unit is switched on but this amounts to only 40mA.

Circuit description

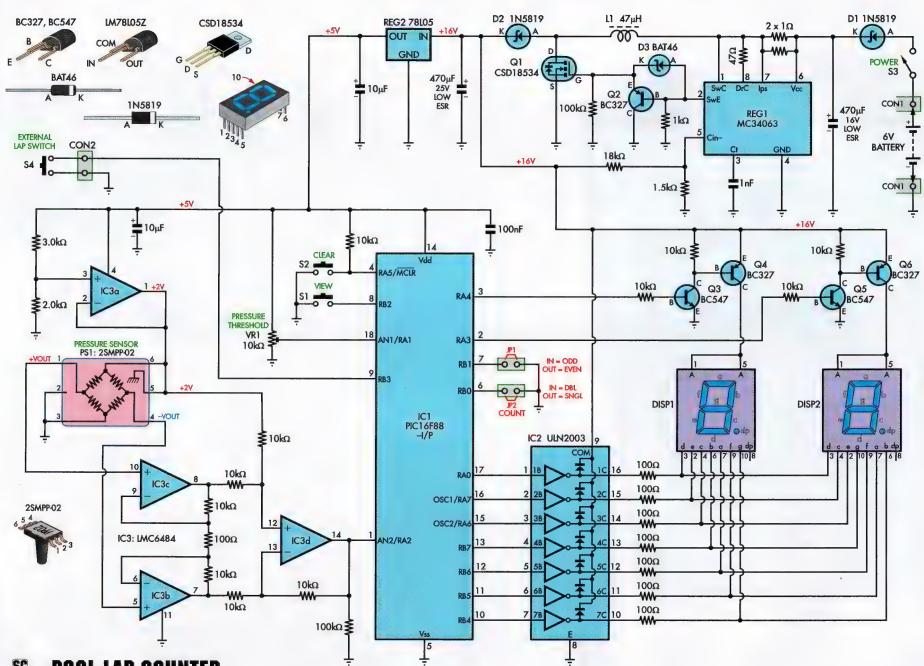
The full circuit for the Lap Counter is shown overleaf and is based around a microcontroller (IC1) that drives the display while monitoring the switches and the pressure sensor signal. The pressure sensor is used in conjunction with the pressure plate to detect when the swimmer has completed a lap.

The display consists of two large (70mm) seven-segment LED digits, labelled DISP1 and DISP2, with each segment (except for the decimal points) comprising a series string of four blue LEDs.

When lit, each segment has a total voltage drop of at least 12V, ie, 3V across each LED. So a supply of more than 12V is required to drive the display, taking into account the voltage lost in the switches and due to current-limiting resistors.

Features and Specifications

Maximum count: .... 99 laps
Trigger method: ..... waterproof pressure plate or momentary switch
Power supply: ..... 6V battery (four AA cells)
Minimum supply: ... 4V
Current drain: ..... 280mA maximum; 40mA with display off.
Battery life: ..... typically at least ten days of use; around 12 hours if display is constantly lit
Display size: ..... 100 x 73mm, each digit 33 x 57mm
Display type: ..... bright blue LED
Multiplex rate: ..... 488Hz (flicker free)
Display on period:.. 0.5-10s or always on; initial default is 5s
Counting delay: ..... 40ms to five seconds; initial default is 5s
Dimming: ..... adjustable in four steps from 25% to full brightness, initial default full brightness



POOL LAP COUNTER

The 2SMPP-02 pressure sensor detects the slight change in pressure when the sensor pad is touched. It doesn't take much to trigger it – just a touch when you turn for the next lap.

Accordingly, the circuit includes a step-up supply based around regulator REG1, inductor L1 and associated components, to produce a steady 16V to be used for driving the display.

Microcontroller IC1 is powered via a 5V regulator (REG2) from this 16V supply, so that the unit can continue to operate even with the battery below 5V, down to 1V/cell (4V total).

To control DISP1 and DISP2, the 5V digital outputs of IC1 need to be level shifted. To achieve this, the common anodes of each display are driven by a two-transistor arrangement. When IC1's RA4 output (pin 3) is high, at 5V, it drives the base of NPN transistor Q3 via a 10kΩ resistor. With Q3 switched on, its collector goes low (near 0V) and this pulls current from the base of PNP transistor Q4 via a 1kΩ resistor, switching it on. Q4 then supplies the common anodes of DISP1's segments with 16V.

Similarly, for DISP2, the RA3 output of IC1 drives Q5 which in turn drives Q6, switching 16V to the common anodes of DISP2.

The cathodes of each segment are driven by IC2, a ULN2003 Darlington array, with 100Ω current limiting resistors. IC2 contains seven Darlingtons in the one package along with clamp diodes (which are not required in this case). Base resistors are included in the package so each input is suitable for direct connection to IC1. IC1 drives IC2's inputs using outputs RA0, RA6 & RA7 and RB4 to RB7.

Note that DISP1 and DISP2 are multiplexed, ie, they are lit alternately with only one set of anodes powered at any given time. This is arranged by ensuring that RA3 and RA4 don't go high simultaneously. This is important since the segment cathodes of DISP1 and DISP2 are connected in parallel and so which segments are lit is determined both by the state of IC2's inputs as well as which of RA3 or RA4 is high.

The displays are multiplexed at 488Hz so there is no visible flicker. There is also a small dead time between when one display switches off and the other is switched on to prevent ghosting. Ghosting is where each display shows a low brightness copy of the other display, due to the cathode drive not switching off before the other display's anode is energised. The dead time is increased when dimming is required, as this reduces the segment duty cycle and thus apparent brightness.

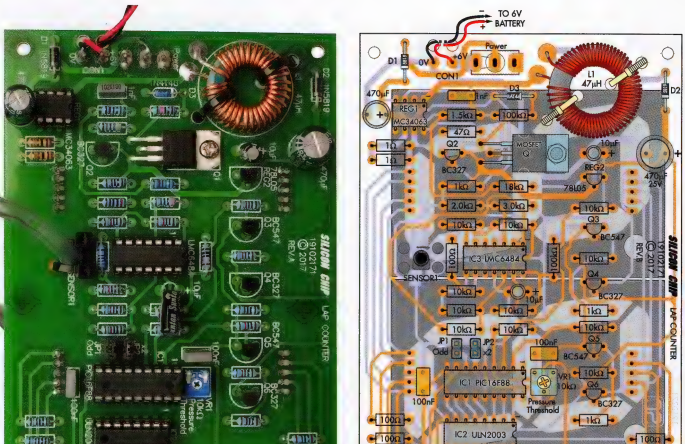
Here's our "sensor pad" – an Esky Cooler Brick which we bought at Bunnings for $5.99. It's flexible enough to send a puff of pressure to the circuit when touched. You can clearly see the points which can be drilled through without risk of any of the coolant inside escaping.

Inputs

IC1 monitors seven inputs. These include the View switch (S1), the Clear switch (S2), the external Lap switch (S4), jumpers JP1 and JP2 along with the wiper position of VR1 and the output of the pressure sensor. All inputs which monitor switches, except S2, have internal pull-up current sources which holds these inputs at 5V unless they are pulled low via the switch or jumper connection closing. Clear switch S2 is connected to IC1's reset input, which has an external 10kΩ pull-up. When pressed, IC1 is reset and the internal software restarts.

The pressure sensor is monitored via the output of op amp IC3d at pin 1 (AN2) while the position of VR1's wiper is monitored at pin 18 (AN1). Both are connected to IC1's internal analog-to-digital converter (ADC). VR1 is used to set the threshold for the pressure sensor while the output of IC3d is an amplified and level shifted version of the signal from the pressure sensor. As the pressure at PS1 increases, IC3d's output voltage also increases. When this voltage exceeds the threshold setting at VR1's wiper, an internal comparator in IC1 is triggered and the software increases the lap count.

Pressure sensor PS1 is configured as a Wheatstone resistance bridge the with voltage at pins 1 and 4 about halfway between the voltage applied across pins 6 and 3. This 2V is derived from the regulated 5V rail via a 3kΩ/2kΩ resistive divider and buffered by unity gain amplifier stage IC3a.



The rear view, or bottom side of the PCB, with the component overlay alongside. (REAR VIEW)

Increased pressure on the sensor causes the voltage at pin 4 of PS1 to drop and the voltage at pin 1 to rise. IC3c and IC3b buffer the voltages at these two points and form part of an instrumentation amplifier with a gain of 100. The gain is set by the ratio of the 10kΩ resistors in the feedback paths for IC3b and IC3c and the 100Ω resistor between them. The differential output from these amplifiers is converted to a single-ended output by IC3d.

IC3d's output is level shifted so that it will not normally go below 0V, due to the 10kΩ resistor from its pin 12 input to the 2V rail. As a result, the output of IC3d sits at around 2V with the sensor exposed only to ambient pressure.

Stepped-up supply

REG1 forms part of a boost regulator, to generate 16V from the 4-6V battery supply. It works in conjunction with inductor L1, diode D2, Mosfet Q1 plus a few other parts. REG1 has an internal compound driver transistor that could be used to directly drive the inductor. However, there is some voltage loss across this transistor, particularly at higher currents.

So we are using its internal transistor as a low-current switch to drive the gate of Mosfet Q1 via schottky diode D3. The Mosfet is switched off when the internal transistor is switched off due to the 1kΩ pull down resistor. When there is no drive from REG1, PNP transistor Q2 is switched on by the base current flow through the 1kΩ resistor, quickly discharging Q1's gate to around 0.7V.

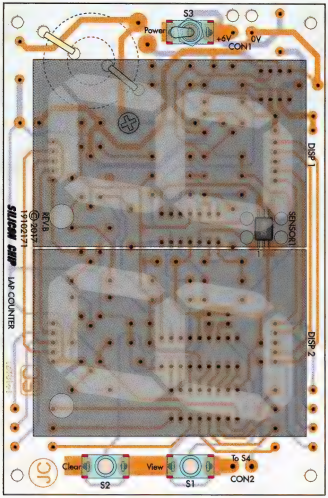
Note that the Mosfet is a low gate threshold type that has a low on-resistance even with a gate voltage of just 3V. This is necessary so the circuit can work down to low supply levels (ie, around 4V).

When the output of REG1 goes high, Mosfet Q1's gate is charged via diode D3 and it switches on, allowing current to flow from the battery supply via reverse polarity protection diode D1, the 0.5Ω current-sense resistor (comprising two parallel 1Ω resistors), inductor L1 and Mosfet Q2 to ground. This charges the magnetic field of inductor L1. REG1 senses when the current through L1 reaches 600mA as this results in a 300mV drop across the 0.5Ω resistor between pins 6 (V_{CC}) and 7 (I_{PS}).

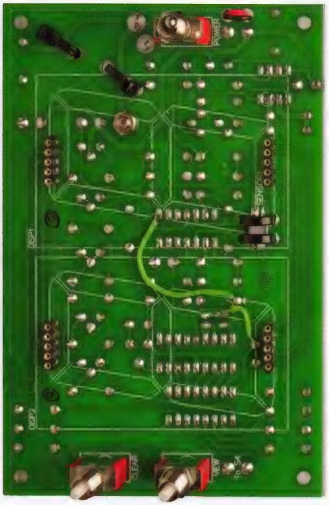
When this current limit is reached, Mosfet Q1 is switched off and the magnetic field in L1's core collapses, producing a high voltage at the anode of schottky diode D2. This flows through D2 to charge the 470µF output filter capacitor.

The voltage across the 470µF capacitor is divided down by an 18kΩ/1.5kΩ divider and applied to feedback pin 5 of REG1 (Cin-). When the output is at 16V, pin 5 is around 1.25V.

REG1 incorporates a 1.25V reference so that when the



(FRONT VIEW)



Similarly, here's the top side, or display side, with the photo not having the LED displays in place for clarity.

feedback voltage at pin 5 is above 1.25V, the output duty cycle is reduced to lower the output voltage. When the feedback voltage is below 1.25V, the output duty cycle increases. This maintains the output voltage at the set value of 16V.

Construction

The Lap Counter is built using a PCB coded 19102171 and measuring 131 x 86mm. This is housed in a UB1 plastic box which measures 158 x 95 x 53mm. The lid is not used and is replaced with a neutral tint or blue-tinted front panel made using 3mm Acrylic or Perspex sheet, measuring 152 x 90mm. This allows the display to be seen through the front panel. Note that the sheet used should be a UV stabilised type or it will not last outdoors.

The PCB has components mounted on both sides; see the overlay diagrams above. The two 7-segment displays (DISP1 & DISP2) and switches S1-S3 are mounted on the front, with DISP1 and DISP2 plugged into four 5-way socket strips. Additionally, the pressure sensor is fitted to this side of the PCB, with its input tube poking through a hole to be accessed from the other side. The remaining components mount on the opposite side of the PCB.

Note that if you don't want to use the pressure plate then pressure sensor PS1 and IC3 are not required. Nor are the resistors connecting to IC3. However, it is necessary to fit the 100kΩ resistor at pin 1 of IC1 to hold this input low.

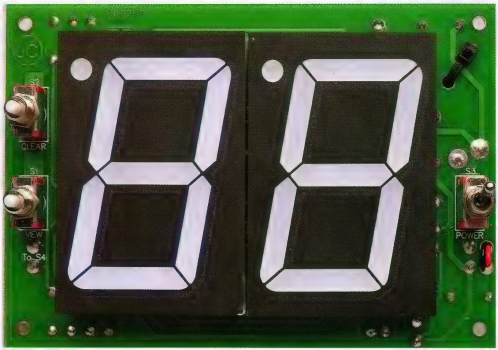
Start by installing the components on the back (ie, non-display) side first. Start with the resistors – the colour code table shows all the codes, however it's a good idea to use a digital multimeter to check each resistor value anyway.

Diodes D1-D3 can be installed now. Make sure they are oriented correctly and note that D3 is a BAT46 while D1 & D2 are 1N5819 types. Next, fit the IC sockets for REG1 & IC1-IC3. Make sure these are oriented correctly (notched side to top) before soldering.

Now fit the two PC stakes for the battery connections at CON1. Transistors Q2-Q6 are installed next, with the top of each transistor 10.5mm above the PCB. You will need to crank their leads out to fit the PCB pads. Make sure that the correct transistors are installed at each position; Q2, Q4 & Q6 are BC327s while Q3 & Q5 are BC547s. REG2 can be fitted now, in a similar manner to the transistors. Next, solder VR1 in place.

Mosfet Q1 is mounted horizontally on the PCB with the leads bent at right angles to insert into the PCB. The metal tab is secured with an M3 screw and nut before soldering its leads. Inductor L1 also mounts horizontally, with the leads bent to insert into the PCB holes and is secured with two cable ties before soldering.

Fit the capacitors next. The electrolytic types must be



Here's the PCB from the previous page complete with the two large blue 7-segment displays. We chose blue because they're very visible, even in broad daylight – but they do require a higher voltage to operate.

oriented with the polarity as shown (longer lead to +) and note that the 25V-rated capacitor is located near diode D2.

Next, install the 2-way screw terminal for CON2 with the openings toward the edge of the PCB. The two-way pin headers for JP1 and JP2 are next. Insert the shorter pin end into the PCB, leaving the longer pins for fitting the jumper shunts later.

Flip the PCB over and snap the 20-way socket strip into four 5-way strips. There are two for each display (DISP1 and DISP2). Having soldered those in place, switches S1, S2 and S3 are next mounted. These can be installed either way around, but note that S3 is the toggle switch.

Now fit the pressure sensor, if you're using it. The air nozzle passes through the hole in the PCB and it must be oriented so its pin 1 is aligned with the pin 1 marking on the PCB. It's a surface-mounting part and you can solder each pin individually to the PCB.

Any solder bridges between pins can be removed with solder wick but note that pins 2 & 3 and pins 5 & 6 are meant to be connected together.

Insert one end of a 250mm length of 3mm PVC tubing into the pressure sensor nozzle and tie the pressure sensor to the PCB by looping two cable ties through the allocated holes in the PCB. The locking block section of the cable ties is positioned on the side of the PCB opposite the displays. After tightening the cable ties, the PVC tubing will be held in place.

Note that a small hole should be made in the tubing to equalise air pressure. The hole should be about 1mm in diameter and can be made using a 1mm drill or by cutting a V-shaped notch in the tubing. Do not push through a hole with a small jeweller's screwdriver as the hole will seal up again. The hole will allow air to slowly enter or exit the tube so that it is at atmospheric pressure but will not prevent the sudden air pressure change when the pressure plate is pushed.

The two 7-segment displays (DISP1-DISP2) are plugged into the socket strips mounted on the top side of the PCB. Cut the display pins to 4mm in length. When mounting these, use the overlay diagram as a guide, ie, install them with the decimal points at bottom. The top surface of the displays should be 15mm above the PCB when finished.

The battery wires can now be looped through the stress relief holes and soldered to the appropriate PCB pins. Solder the other end to the battery holder, being careful to ensure you use the correct polarity (if it's reversed, nothing bad will happen, the unit simply won't work).

Front panel

Templates for the drilling and cutting front panel, rear and side sections of the box can be downloaded from the SILICON CHIP website (**www.siliconchip.com.au**) and can be found via the Shop page for the March 2017 issue.

As mentioned, the lid is replaced by a UV-stabilised Perspex or Acrylic tinted sheet covering the full size of the box at 152 x 90mm. A pre-cut Acrylic sheet with rounded corners and mounting holes can be purchased from SILICON CHIP, to save you the hassle of doing it yourself and this will give a neat result. This will already have all the required holes.

If you're making the lid yourself, drill pilot holes in the seven locations indicated. These can be further drilled out to size. It's 3mm for the corner holes and 6.5mm for the switches. These are made larger with successively larger drills or using a reamer to enlarge them out. Take extra care drilling as the plastic can crack if the drill or reamer is forced into the hole.

One end of the box will require drilling for the cable gland that should be located near the base of the box. You will need the cable gland for the plastic tubing from the pressure sensor if you intend to use the pressure plate for lap sensing.

If you intend to use a pushbutton switch instead our end-of-lap sensor plate, the gland is used for the wiring to that switch from CON2.

The AA cell holder is mounted against the base of the box and secured with double-sided foam-core tape. The PCB is held onto the lid of the case by the three switches.

Use both nuts for each switch to secure the assembly in place.

Testing

Plug REG1 into its socket (ensuring it has the correct orientation) and apply power. Check that the voltage between the 0V terminal of CON1 and the cathode of diode D2 is around 16V. Also, check that the voltage between pins 5 and 14 of IC1's socket is close to 5V (4.75-5.25V). The voltage between pins 11 and 4 of IC3 should also be close to 5V (same as IC1).

If this is correct, switch off and plug IC1, IC2 and IC3 into their sockets, again being careful with polarity and to avoid bending any leads under the IC package when doing so. With power reapplied, DISP2 should show 0. DISP1 will be unlit due to leading zero blanking that is incorporated in the Lap Counter software.

The display will go off after around five seconds. It will light again if View switch S1 is pressed or Lap switch S4 (if installed) is pressed. Note that the count will not increase if the Lap switch is pressed before the counter delay period has expired. The initial setting for the counter delay is five seconds.

If a pressure plate is being used, adjust VR1 fully anticlockwise and the display will continuously increment every five seconds. Slowly rotate VR1 clockwise until the counting ceases. You can then test the pressure plate to check that the display counts up when it is pressed. As before, the count will not increase if the pressure plate is pressed before the counter rate limit period has expired.

Dimming

Press and hold View switch S1 for six seconds and the display will dim in steps. Release the View switch when the display is at the required brightness.

Display on time adjustment

The display on-time is adjustable. This is set by pressing and holding View switch S1 and then pressing and releasing Clear switch S2. Keep holding the View switch for five seconds until the letter U is shown on DISP2. The on period is then set using trimpot VR1 (which normally sets the pressure sensor threshold). The on time is adjustable from 0.5s (VR1 fully anticlockwise) up to about 10 seconds

Parts list – Pool Lap Counter

1 double-sided PCB coded 19102171, 131 x 86mm
1 UB1 jiffy box, 158 x 95 x 53mm
1 neutral or blue-tinted 3mm Acrylic or Perspex sheet, UV stabilised, 152 x 90mm [available pre-cut from the Silicon Chip online shop]
1 MEMS Gauge pressure sensor, 0-37kPa (PS1); [Omron 2SMPP-02 – element14 Cat 2113270]
2 LBT23101BB 2.3-inch blue common anode 7-segment displays (DISP1,DISP2) [available from the Silicon Chip online shop]
1 47µH 3/5A toroidal inductor (L1) [Jaycar LF-1274, Altronics L6517]
1 four cell AA holder, single layer type [Jaycar PH9204 or PH9282, Altronics S5028 or S5030]
1 battery snap lead [if required to connect to battery holder]
4 AA alkaline cells
2 SPDT PCB-mount momentary pushbutton switches (S1,S2) [Altronics S1393]
1 SPDT PCB-mount toggle switch (S3) [Altronics S1315]
1 2-way PCB-mount screw terminal, 5.08mm pin spacing (CON2)
1 DIL18 IC socket (for IC1)
1 DIL16 IC socket (for IC2)
1 DIL14 IC socket (for IC3)
1 DIL8 IC socket (for REG1)
1 20-way IC socket strip (for DISP1 & DISP2)
2 2-way pin headers with jumper shunts (JP1,JP2)
1 M3 x 6-10mm machine screw and nut
4 100mm cable ties
1 cable gland to suit 3-6.5mm cable
2 PC stakes
1 250mm length light duty twin lead or red/black light duty hookup wire
1 100mm length foam-core double-sided tape

Semiconductors

1 PIC16F88-I/P microcontroller programmed with 1910217A.hex (IC1)
1 ULN2003N Darlington transistor array (IC2)
1 LMC6484AIN quad rail-to-rail op amps (IC3)
1 MC34063AP switching regulator (REG1)
1 78L05 5V 100mA linear regulator (REG2)
1 CSD18534low gate threshold N-channel Mosfet (Q1)
3 BC327 PNP transistors (Q2,Q4,Q6)
2 BC547 NPN transistors (Q3,Q5)
2 1N5819 1A schottky diodes (D1,D2)
1 BAT46 schottky diode (D3) [Jaycar ZR-1141]

Capacitors

1 470µF 16V low-ESR PC electrolytic
1 470µF 25V low-ESR PC electrolytic
2 10µF 16V PC electrolytic
2 100nF MKT polyester
1 1nF MKT polyester

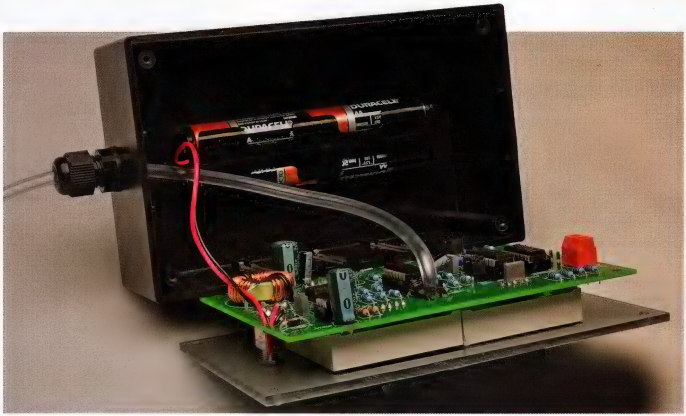
Resistors (0.25W, 1%, metal film)

2 100kΩ 1 18kΩ 11 10kΩ 1 3kΩ 1 2kΩ 1 1.5kΩ
3 1kΩ 7 100Ω 1 47Ω 2 1Ω (5%)
1 10kΩ miniature horizontal trimpot (VR1)

Additional parts for pressure plate

(Parts normally available from hardware stores such as Bunnings)

1 length of 3mm (ID) / 5mm(OD) clear vinyl garden irrigation tubing
1 large flat cooler brick, 320 x 200 x 17mm [eg, Esky Ice Wall 1287091]
2 4mm barbed off-takes (joiners) for tubing [eg, for "Pope" drip-feed watering system]
1 stainless steel bracket or 2-4 suction cups [see text and diagram]



The only "component" which mounts in the case itself is the 4xAA battery pack (secured with double-sided tape). Everything else "hangs" off the front panel/lid, with the two 7-segment displays obviously toward the front. The clear tube you can clearly see coming from the case goes off to our custom-made pressure sensor plate.

with VR1 near fully clockwise. The midpoint setting gives the original five second on time. With VR1 fully clockwise, the display remains on as long as power is applied.

Counter delay period

The counter delay period (maximum count rate) is also adjustable. This is set by connecting a pushbutton switch to the S4 input at CON2. Press and hold this switch closed and then press and release the Clear switch, S2. Keep holding S4 for five seconds until the letter C shows on DISP2.

The counter period is then set using trimpot VR1. The delay period is adjustable from 1/25 second (40ms) at VR1's fully anticlockwise position, up to about 5 seconds with fully clockwise rotation.

Note that after setting either the on time or counter delay, VR1 should be returned to its original position to restore correct pressure sensor operation (assuming you have fitted one).

Don't forget to select the count option using shunts on JP1 and JP2. For normal single number counts (0,1,2,3,...), leave JP1 and JP2 off. For odd number counting (0,1,3,5,...), insert both jumpers JP1 and JP2 while for even number counting (0,2,4,6,...), insert JP2 but leave JP1 out.

Pressure plate assembly

The pressure plate is made using a large, slim freezer brick. We used an "Esky" brand which we bought at Bunnings Hardware for $5.99 (model No. 1287091).

Measuring 320 x 200 x 17mm, this has a gel inside and we leave it there so that the brick won't float in the pool.

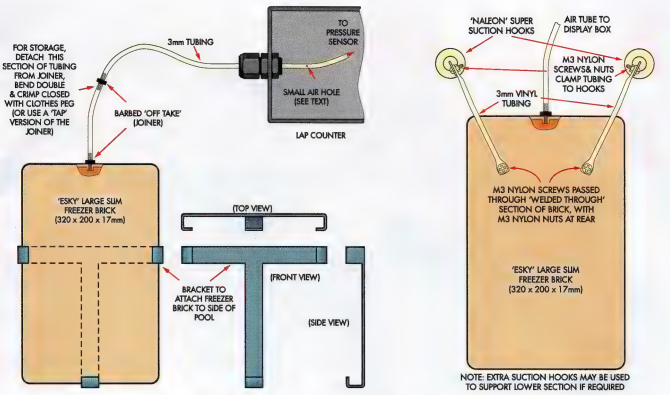
The top lid of the brick is drilled to 4mm and a 4mm barbed off-take is inserted. A length of 3mm PVC tubing can then be attached to this barb. A second off-take is used to join to a longer PVC tube to the Lap Counter unit.

While the tubing is 3mm and the barb 4mm, the tubing will stretch over the barb connector. If you find it difficult to fit, soak the tube end in hot water for a few seconds to soften the PVC.

The pressure (sensor) plate (ie,

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	1	18kΩ	brown grey orange brown	brown grey black red brown
❑	11	10kΩ	brown black orange brown	brown black black red brown
❑	1	3kΩ	orange black red brown	orange black black brown brown
❑	1	2kΩ	red black red brown	red black black brown brown
❑	1	1.5kΩ	brown green red brown	brown greenblack brown brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	7	100Ω	brown black brown brown	brown black black black brown
❑	1	47Ω	red purple black brown	red purple black gold brown
❑	2	1Ω	brown black gold brown	brown black black silver brown



Here are two methods of mouting the freezer brick on the end of the pool (you may think of others to suit your pool). The first is to fashion a bracket in marine-grade stainless steel as shown at left. However, it may be difficult for the average person to work with stainless steel. If you use aluminium instead (because it is much easier to work!) remember that the chemicals in your pool will start attacking aluminium quite quickly, so the bracket cannot be left in the pool. The alternative "suction cup" method (as shown at right and in the photo below) will only work if your pool has glazed (ie, shiny!) tiles; the suction cups will not "suck" on a rough surface.

freezer brick) is located at the end of the pool in a vertical position.

Note that during transportation, you need to either keep the brick upright or crimp the hose and hold it closed with a cable tie or peg to prevent the gel escaping.

The pressure plate can be mounted using various methods. For pools with glazed (ie, shiny!) tiles, a pair of suction cups with thin cord (or even lengths of the 3mm PVC tube we used earlier) will hold it in place (four suction cups could be used for extra stability).

Otherwise, a suitable stainless steel bracket can be secured to the pool or hung over the edge on an above-ground pool.

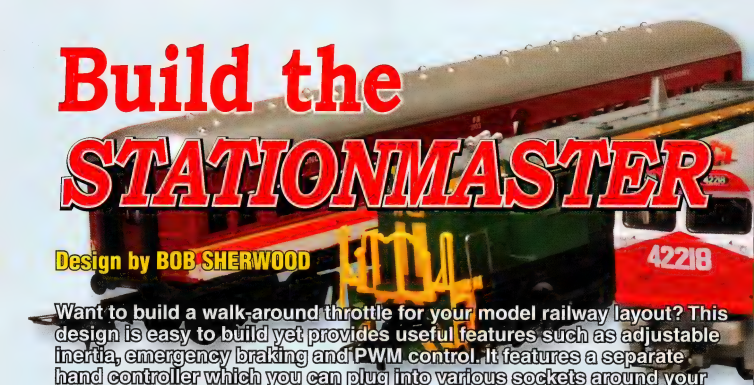
Note that PVC tubing and the freezer brick are not suitable for extended exposure to sunlight.

It is recommended to store these away in the shade when not in use, especially during the summer.

OK, with the remaining warm days of early autumn, it's time to start swimmin those laps in your pool. At least you'll be able to keep a count! SC

The second method of mounting the sensor using suction cups on shiny tiles – it won't work on pebblecrete or rough tiles! You can carefully drill through the cooler brick to attach cord or tube where there are dimples in the moulding. Incidentally, the sensor doesn't need to be wholly under the water – half in and half out works just as well.

Build the STATIONMASTER



Design by BOB SHERWOOD

Want to build a walk-around throttle for your model railway layout? This design is easy to build yet provides useful features such as adjustable inertia, emergency braking and PWM control. It features a separate hand controller which you can plug into various sockets around your layout. That way you can closely watch your favourite locomotives as you drive them around your layout.

While **Digital Command Control (DCC)** is the bee's knees for large model railway layouts, a simple walk-around throttle is all you need for smaller layouts. And of course, there is nothing to stop you using this controller on a large layout, as well.

The benefit of a speed controller with a hand-held walk-around controller is that you can plug it into sockets at various points around your layout. This Stationmaster design by Bob Sherwood uses cheap, readily available Telecom-style RJ sockets and plugs. Your layout can have one socket or many, depending on how many you want and you can use standard flat or curly leads.

Chances are you already have a spare AC or DC power supply that would be suitable to run the Stationmaster. Anything from 12V DC or 10VAC at 1A up to 25V DC or 18VAC at 5A would do the job; 1A will be plenty for a single locomotive while if you're planning to run several on the same tracks, you will need at least two or three amps.

If you already have a train controller but it's a variable DC output type, you will want to upgrade to the Stationmaster because as you have probably noticed, any time the locomotive hits a dirty section of track at a low DC voltage, it tends to slow down, lurch or even stop. That's much less of an issue with PWM (pulse width modulation) drive because you will be applying higher peak voltages to the track.

Features & Specifications

- Walkaround hand controller
- Controls: forward/reverse, speed, inertia (momentum), emergency brake
- Indicators: power on, forward/reverse drive, track voltage indicators
- Short-circuit protection
- Output current: up to 3.5A; adjustable current limit
- Supply voltage: 12-25V DC, 10-18VAC
- Quiescent current: 20mA
- PWM frequency: ~8kHz

The PWM voltage is applied to the track by an H-bridge IC. The operation of an H-bridge is shown in Fig.1 and four possible switch conditions are shown. Here we are showing the H-bridge as comprising four switches although in the Stationmaster they are N-channel Mosfets.

Fig.1(a) shows the default state with all switches off. In this state the motor is not connected to anything and so if the locomotive is moving, it will continue to move but will slow down naturally due to friction in the wheels, gearing and motor. If the locomotive is not moving, it would be possible to push it along the track and it may roll down a steep grade on its own.

In Fig.1(b), switches S1a and S2b are closed. One end of the motor is connected to the positive supply and the other end to ground, so the motor is driven in one direction. In Fig.1(c), the opposite pair of switches is closed and so the motor drive polarity is reversed and the motor will rotate in the opposite direction.

In Fig.1(d), switches S1b and S2b are closed and so the motor is effectively shorted out. This will provide significant braking. If the locomotive is moving, it will quickly come to a halt and if it is stationary, it will be difficult to move and will not roll down a steep

Walkaround Throttle for Model Railways

grade. If the opposite set of switches were closed (ie, S1a and S2a), the effect would be the same.

All four switches plus the control logic and gate drive circuitry in the Stationmaster are integrated into a single IC, a Texas Instruments DRV8871 H-bridge. One important feature of this IC is that it contains protection logic to prevent the wrong pair of switches from being closed whereby the power supply would be shorted out.

Speed control is achieved by switching rapidly between the configuration of Fig.1(a) and either of Fig.1(b) or Fig.1(c), depending on the direction of travel.

The more time the H-bridge spends in the state of Fig.1(a), the lower the locomotive speed. With a PWM control scheme, the rate at which the H-bridge alternates between these configurations is fixed and speed is controlled by how much time it spends in the two states. The percentage of the time where voltage is applied to the tracks is known as the duty cycle; a higher duty cycle results in a higher speed.

Circuit description

The complete Stationmaster circuit is shown in Fig.2 and it consists of two main sections. At left is the PWM waveform generation circuitry and at right, the DRV8871 H-bridge IC and associated components, to provide the high-current drive to the locomotive tracks.

The PWM generation circuitry is based on IC1, a TL084 and IC2, an MC14584 hex schmitt trigger inverter. Two of the op amp stages, IC1a and IC2b, combine to form an ~8kHz triangle wave generator. IC1b is configured as an integrator, with its pin 5 non-inverting input connected to a 2.5V half-supply rail derived from the 5V rail via two 220Ω resistors and a 1µF filter capacitor.

When its pin 6 inverting input is above 2.5V, the output voltage at pin 7 drops at a constant rate whereas when the pin 6 input is below 2.5V, the output voltage at pin 7 rises at the same rate. Op amp stage IC1a is configured as a comparator with hysteresis and its output is low when its pin 3 input is below 2.5V and high when its input is above 2.5V.

This input is fed via a divider from

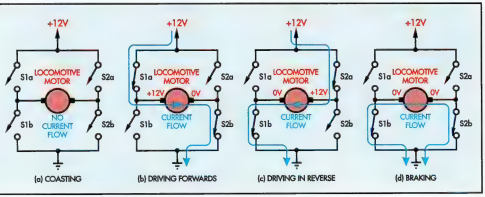


Fig.1: four of the five possible configurations of an H-bridge (the fifth is not used in our application). The voltage across the motor and the current flow path is shown, assuming a nominal 12V DC supply. In case (d), the current flow direction depends on the direction of motor rotation at the time of braking. The switches are usually discrete Mosfets (they may also be internal to an IC) as in the Stationmaster.

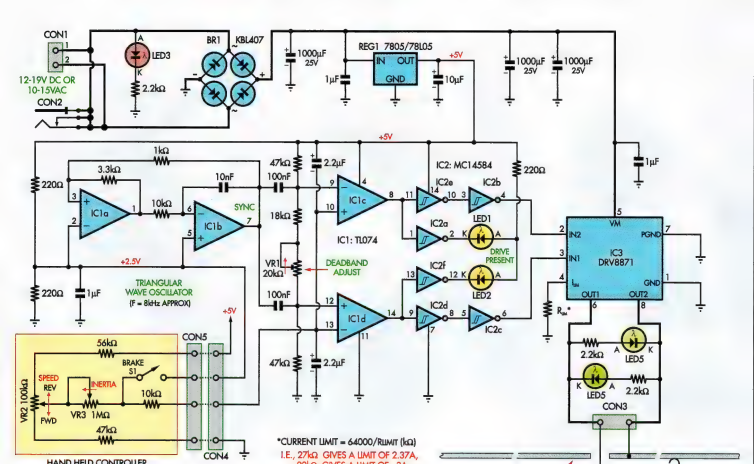


Fig.2: the complete circuit diagram for the Stationmaster, with the hand controller circuitry shown in the box at lower left. IC1a and IC1b generate a triangle waveform at around 8kHz and IC1c and IC1d compare this to the control signal from speed pot VR2. The outputs of IC1c and IC1d are PWM signals which are squared up by schmitt trigger inverter IC2 and fed to H-bridge IC3 to drive the tracks.

the output of IC1b, with the other end of the divider connected to its pin 1 output. So essentially, this completes the feedback path causing IC1b to oscillate as well as defining the amplitude of the triangle wave it produces, by the ratio of the 1kΩ and 3.3kΩ resistors.

When output pin 1 of IC1a is low, at say 0.9V, output pin 7 of IC1b will need to rise above 3V in order to switch the output of IC1a high. You can confirm this by calculating the voltage at pin 3 (in the middle of the divider): (3V × 3.3kΩ + 0.9V × 1kΩ) ÷ (3.3kΩ + 1kΩ) = 2.51V. Similarly, when output pin 1 of IC1a is high, at say 4.05V, output pin 7 of IC1b will need to fall below 2V in order to switch the output of IC1a low; (2V × 3.3kΩ + 4.05V × 1kΩ) ÷ (3.3kΩ + 1kΩ) = 2.48V.

So these will be the approximate maximum and minimum voltages of the triangular waveform at output pin 7 of IC1b, with a maximum of around 3V, a minimum of around 2V and thus a peak-to-peak voltage of around 1V.

The actual waveforms produced by the prototype are shown in the oscilloscope grab of Fig.3. The waveform at pin 1 of IC1a is the green trace while that at pin 7 of IC1b is the blue trace. As you can see from the measurements at the bottom of the screen, the actual peak-to-peak voltage of the triangle wave is 880mV and the frequency is 9.43kHz (the actual frequency will vary depending on circuit tolerances but it is not critical).

The triangular wave is converted into a variable duty cycle PWM signal by comparing its amplitude to that of a DC control signal which varies somewhere between its minimum and maximum voltages. The higher the control signal voltage, the higher the PWM duty cycle. However, the situation is complicated by the fact that we need to be able to drive the locomotive in either direction and that we also need a "dead band" when the speed pot is set somewhere around the middle, where there is no drive at all.

This situation is handled by using two comparators along with two triangle waveforms that have slightly different DC levels. The other two stages of op amp IC1, ie, IC1c and IC1d are used for these comparators and the waveform from the pin 7 output of IC1b is coupled to two of their inputs (pins 9 and 12) via 100nF capacitors. The DC bias for these two pins is

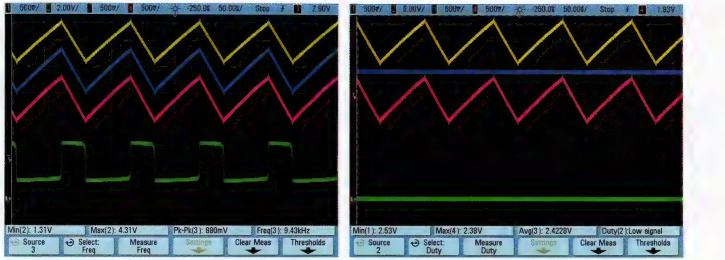


Fig.3 (left): the blue trace is the triangle waveform at pin 7 of IC1b. It has a frequency of 9.43kHz and an amplitude of 880mV peak-to-peak. The yellow and mauve traces are the DC-shifted versions of this waveform at pins 10 and 13 of IC1 respectively. The green trace shows the pulse applied to pin 6 of IC1b which are in-phase with the triangle waveform and have a maximum voltage of 4.31V and minimum of 1.31V, limited by the drive capability of the op amp.

Fig.4 (right): the same voltages from pins 10 and 13 of IC1 are shown here but the blue trace now shows the reference voltage from speed pot VR2. Since it is below the yellow trace and above the mauve trace, no drive is applied to the tracks and the PWM output at pin 4 of IC2b, shown in green, is a flat line (ie, there is no PWM signal to tracks).

provided by a resistor network across the 5V supply comprising two 47kΩ fixed resistors, an 18kΩ resistor and 20kΩ trimpot VR1 which is connected as a rheostat (ie, variable resistor).

Thus, input pin 9 of IC1c has a DC level between 2.84V and 3.22V while input pin 12 of IC1d has a DC level between 1.78V and 2.16V, depending on the setting of VR1. The average of these two voltages will be very close to the 2.5V half supply rail. The further apart these two voltages are, the larger the "dead band" will be, allowing the speed control potentiometer to be rotated over a larger part of its range without any drive to the locomotive.

This adjustment is necessary to allow for variations in the amplitude of the triangle waveform; VR1 is adjusted until the waveforms no longer overlap, so that there is no drive to the locomotive tracks with the speed pot in its central position.

Also, there's no guarantee that when its speed pot is in its half-way position, it will necessarily be at exactly half its nominal resistance value. Indeed, if using a pot with a central detent, it would be very annoying if the loco slowly moved in one direction or the other. So the dead band needs to be so that the loco tracks get no drive with the speed pot at its half-way point.

The two DC-biased triangle waveforms can also be seen in Fig.3, with pin 9 of IC1c in yellow and pin 12 of IC1d in mauve. As you can see, VR1 has been adjusted so that the minimum voltage of pin 9 is above the maximum voltage of pin 12.

Speed, inertia & brake controls

The speed, inertia and brake controls consist of two pots and a momentary switch and are normally mounted in the separate hand controller unit which is attached to the main board by a telephone cable.

Normally, a 2-metre cable is about right however you can use a longer or shorter cable if necessary. There are provisions to mount these controls inside the main unit, however, we won't go into details about that option since we think most people will want to use the hand controller for walk-around operation.

The controls are shown at lower left in the circuit of Fig.2. Speed control pot VR2 is effectively connected across the 5V supply with padding resistors at either end to limit the voltage at its wiper so that it varies over an appropriate range to go from full speed in the forward direction to full speed in reverse, without too much of a dead zone at either end.

The inertia potentiometer is wired as a rheostat (variable resistor) and is in series with the return signal from the speed pot's wiper. The other end of the inertia pot is fed to a pair of 2.2μF capacitors on the main board, via a 10kΩ fixed resistor, so the higher a resistance the inertia pot is set to, the more slowly the voltage across these 2.2μF capacitors change. This simulates a locomotive with more inertia (mass), so its speed will change more slowly when the speed pot is rotated.

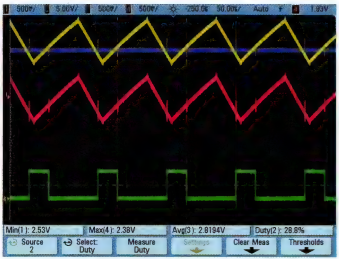
Brake switch S1 bypasses both the speed and inertia pots and connects the 2.5V mid-rail supply directly to the 10kΩ capacitor, which rapidly charges/discharges the 2.2μF capacitors on the main board until the locomotive has stopped and it will remain stopped until the brake switch is released; if the speed pot is at its midpoint after the brake is released, the loco will not move off again.

Note that braking is not instant as this may cause the locomotive(s) to derail but it will stop the loco(s) significantly faster than simply winding the speed pot back to its central position.

Track drive

The output of op amp (comparator) IC1c goes high when the speed control signal at its pin 10 non-inverting input is above the triangle waveform at its pin 9 inverting input, thus, its output duty cycle increases with clockwise rotation of the speed pot.

Similarly, the output of op amp (comparator) IC1d goes high when the speed control signal at its pin 13 inverting input is lower than the triangle waveform at its pin 12 non-inverting



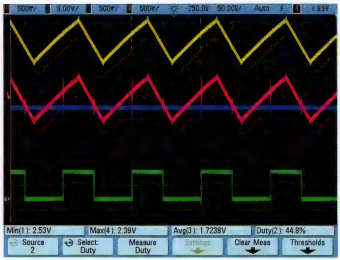


Fig.5 (left): the same traces as in Fig.4 but now the speed pot has been rotated clockwise, increasing the reference voltage (shown in blue). When the yellow waveform is below the blue reference voltage, the PWM output at pin 4 of IC2b, shown in green, increases to 5V and it drops back to 0V when the yellow and blue waveforms cross again. Thus, as the speed pot is rotated further clockwise, the PWM pulses at pin 2 of IC3 (IN2) increase in duty cycle.

Fig.6 (right): now speed pot VR2 has been rotated anti-clockwise past its centre position, so the reference voltage, shown in blue, has now dropped low enough to intersect with the mauve waveform. The green trace now shows output pin 6 of IC2c, which feeds input IN1 (pin 3) of IC3. Note that the positive edge of the PWM pulses is now delayed compared to the crossing point, due to the limited bandwidth of op amp IC1 however the speed pot can still be used to adjust the PWM duty cycle.

input, thus, its output duty cycle increases with anti-clockwise rotation of the speed pot.

As stated earlier, VR1 is adjusted so that the output of both comparators remain constantly low with the speed pot at its halfway point. This condition is shown in the scope grab of Fig.4. The blue trace is the reference voltage from speed pot VR2. Since it is below the yellow trace and above the mauve trace, no drive is applied to the tracks and the PWM output at pin 4 of IC2b, shown in green, is a flat line.

Drive from both op amps (comparators) is fed to four of the six schmitt trigger inverter stages of IC2. IC2a and IC2f invert these signals and then drive LED1 and LED2, which have a common 220Ω current-limiting resistor. Hence, as the locomotive moves faster in the forward direction, LED1 lights up brighter (as it has a higher duty cycle) and similarly, the brightness of LED2 indicates the drive speed in the reverse direction.

The remaining four inverter stages are wired up in two series pairs, effectively forming buffers to square up the signals from IC1c and IC1d and pass them to the inputs of integrated H-bridge IC3.

With IN1 and IN2 (pins 3 and 2) of IC3 both low, there is no output drive. With IN1 high, OUT1 (pin 6) is driven high while OUT2 (pin 8) is driven low. With IN2 high, OUT1 is driven low while OUT2 is driven high, reversing the locomotive. And with IN1 and IN2 both high at the same time, both outputs are driven low to provide motor braking, however, that feature is not used in this circuit.

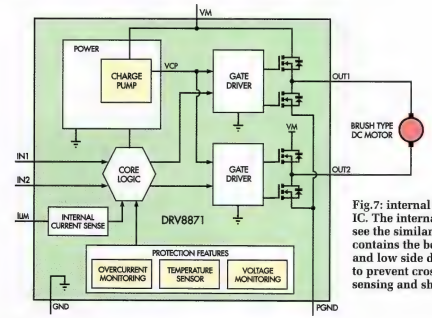


Fig.7: internal block diagram for the DRV8871 H-bridge IC. The internal Mosfets are shown at upper-right; you can see the similarity in their connections to Fig.1. The IC also contains the boost circuitry to produce the required high and low side drive signals to the Mosfet gates, control logic to prevent cross-conduction plus current and temperature sensing and shutdown.

PWM output waveforms

We previously referred to the scope waveforms of Fig.3 and Fig.4 with the latter showing the condition where the speed control pot VR2 is centred, so there is no output at pin 2 of IC3 (IN2, green), nor at pin 3 (IN1, not shown).

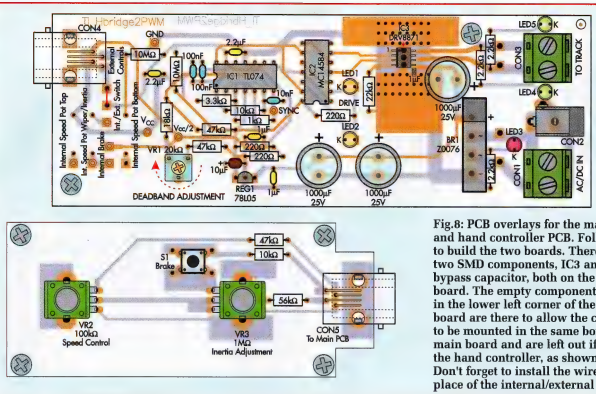


Fig.8: PCB overlays for the main PCB and hand controller PCB. Follow these to build the two boards. There are only two SMD components, IC3 and its 1µF bypass capacitor, both on the main board. The empty component positions in the lower left corner of the main board are there to allow the controls to be mounted in the same box as the main board and are left out if built with the hand controller, as shown here. Don't forget to install the wire link in place of the internal/external switch.

In Fig.5, we have rotated VR2 partway clockwise and this has caused the control voltage (blue trace) to rise to 2.82V. As a result, pulses now appear at pin 2 of IC3 (IN2, green) with a duty cycle of 28.8%. You can see that the leading edges of these pulses correspond to the point where the yellow trace dips below the blue trace and the trailing edges are where they cross over again, so the higher the blue (control) voltage, the greater the applied duty cycle will be.

Fig.6 shows the situation with VR2 rotated anti-clockwise from its central detent, reducing the control voltage (blue trace) to 1.72V. The green trace now shows the voltage at pin 3 of IC3 (IN1) which has a duty cycle of 44.8% and the edges correspond to the points where the blue and mauve traces intersect.

H-bridge IC details

The internal block diagram of the DRV8871 IC is shown in Fig.7. It has four internal N-channel Mosfets with parallel diodes which form the H-bridge which drives the motor, the circuit blocks to control the Mosfets' gates, the charge pump to generate the required high-side and low-side gate drive voltages and the various control and protection units within.

This IC has a current limiting facility which both protects it from damage and also helps the unit withstand accidental short circuits across the track, as will inevitably happen on any model layout, particularly when a locomotive is derailed. The maximum output current depends on the value of R_{LIM} which connects between the I_{LIM} pin and ground. The IC is rated for up to 3.6A peak, so a current limit of around 3A as set by R_{LIM} = 22kΩ is quite safe.

Should IC3 overheat due to extended high current delivery, it will automatically shut down until it has cooled sufficiently and then resume operation. IC3 also has an internal "dead time" delay to prevent cross-conduction of its internal Mosfets, which means that the driving circuitry can change the state of inputs IN1 & IN2 at any time without any chance of damaging the IC.

Referring back to Fig.2, IC3 also has an SMD ceramic 1µF bypass capacitor to help stabilise the output voltage and provide a relatively clean square wave for driving the motor. Note that IC3 has integral diodes between each output and the two supply rails, to clamp any inductive spikes from the locomotive motor(s). It is purpose-designed for driving motors.

LED4 and LED5 are connected across the track outputs in opposite directions with 2.2kΩ current-limiting resistors and so normally echo the brightness of LED1 and LED2 respectively, however, if there is a short across the track, LED1/LED2 will still light while LED4/LED5 will be off or dim. Note that LED4 and LED5 are located near the output terminal and are visible with the lid on the case.

Power supply

The power supply is quite simple and accepts either 10-15VAC or 12-19V DC. Actually, all the components should survive with a supply as high as 25V DC or 18VAC, should you wish to push it close to its limiting values.

LED3 is connected directly across the inputs and so will light solidly with a DC input or flicker with reduced brightness at 50Hz with an AC input. Either CON1, a 2-way terminal block, or CON2, a DC barrel connector can be used. We suggest you stick with the terminal block if your power supply is rated at more than 2A.

The input supply is rectified by bridge rectifier BR1 and this means that with a DC supply, the polarity of the connection is not important. The output of the rectifier is filtered with two parallel 1000µF capacitors, smoothing any ripples in the DC and also providing AC to DC conversion if required (in combination with BR1). The resulting DC is fed straight to the motor controller IC, IC3 and also to the

Fig.9: drilling and cutting diagrams for the main box. The top panel drilling template can also be used as the panel label.

input of 5V regulator REG1.

REG1 has a 1µF input bypass capacitor and 10µF tantalum output filter capacitor and supplies IC2, IC3 and the two divider networks.

Construction

The Stationmaster is built on two PCBs. The main board is coded 09103171, measures 143.5 x 50.5mm and hosts most of the components while the hand controller board is coded 09103172, measures 98 x 40.5mm and is fitted with the components shown in the yellow box in Fig.2.

Use the overlay diagrams in Fig.8 as a guide to construction, which is quite straightforward. The only slightly tricky component is IC3, which is only available in a surface-mount package, so start by soldering this. This has the additional twist that the underside of the IC features a metal pad which needs to be soldered to the PCB to provide sufficient heatsinking.

If you have a hot air rework station, all you need to do is apply a thin layer of solder paste to the central pad and eight pins for IC3, drop the IC in place (ensuring its pin 1 dot is orientated as shown in Fig.8) and then gently heat the IC until all the solder reflows. You can check that the solder underneath

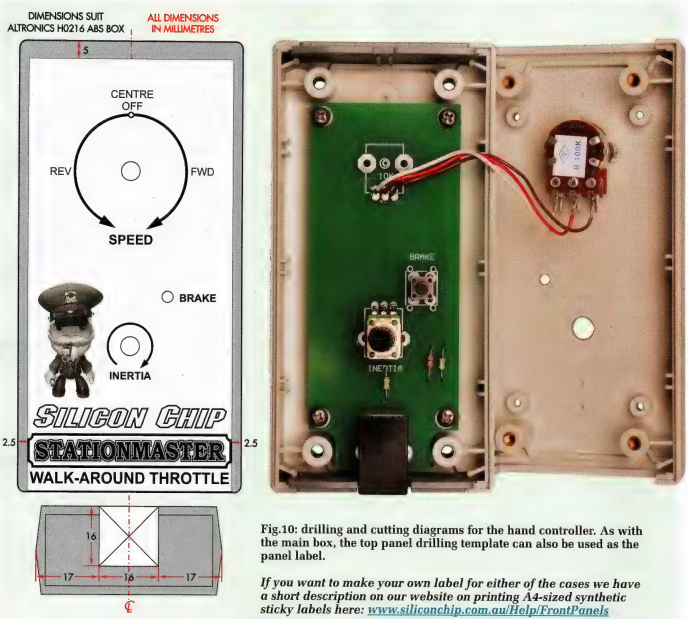


Fig.10: drilling and cutting diagrams for the hand controller. As with the main box, the top panel drilling template can also be used as the panel label.

If you want to make your own label for either of the cases we have a short description on our website on printing A4-sized synthetic sticky labels here: *www.siliconchip.com.au/Help/FrontPanels*

the IC has melted properly by examining it from the underside of the board through the three large vias positioned under IC3, once the board has cooled sufficiently.

If you don't have a hot air tool, we suggest you place a thin layer of solder paste (or in a pinch, flux paste) on the central pad for IC3, then position it as explained above and tack solder one of the eight pins using a regular soldering iron.

Check that the IC is sitting flat on the board and properly positioned over its pads and then solder the remaining pins, then refresh the first pin which was tack-soldered. If any bridges form between its leads, clean them up using solder wick.

You can then flip the board over and melt some solder into the three large vias under the IC. Leave the iron in contact with this pad for a few seconds to ensure that the new solder remains molten and sufficient heat conducts through to the other side of the board to reflow the solder paste. That should do the trick and you can then remove any excess solder on the underside pad using a solder sucker or some solder wick.

There are also two small sets of SMD pads on either side of IC3 and the one to lower right is for the 1µF bypass capacitor. This is pretty easy to solder, simply tack solder one end, wait for the solder to cool, solder the other end (being careful to ensure the solder flows onto both the PCB pad and the end of the capacitor) and then apply fresh solder to the first joint.

Through-hole parts

With IC3 in place, the rest is pretty straightforward. Fit the 15 small resistors in the locations shown in Fig.8. It's a good idea to check the values with a DMM before fitting as the colour bands can be hard to identify accurately.

If you are using IC sockets, now is a good time to install them, making sure to orientate the notches as shown in the overlay diagram. Otherwise, solder the other two ICs directly to the PCB but be careful to make sure that you don't get them mixed up and that the pin 1 dot goes in the location shown.

Next, install all the small capacitors. The values are indicated on the overlay diagram. The capacitors of 1µF and above have a polarity (+) indicator, however, note that only the 10µF capacitor is actually polarised and this should have a matching + sign printed on its body, which must be lined up with that on the PCB.

LEDs 3-5 can now be fitted, taking care to orientate them with the flat side of the lens/shorter lead (cathode) to the right/bottom of the board, where indicated with "K" on the PCB overlay. These are pushed all the way down onto the PCB before being soldered and the leads trimmed.

You can now fit the PCB stakes if you want to, however, it isn't necessary and you can simply probe these pads with DMM leads if necessary to troubleshoot the circuit.

Now mount trimpot VR1 and regulator REG1. You will need to crank REG1's leads to fit the solder pads and make sure it goes in the right way around, with its flat face towards the nearest edge of the PCB. Note that a 7805 regulator can be used instead and in this case, its metal tab faces the edge of the PCB.

Next on the list are DC connector CON2 and RJ12 connector CON4, both of which should be pushed all the way down onto the PCB before you solder their pins. You can then follow with terminal blocks CON1 and CON3 which must be fitted with their wire entry holes towards the right edge of the board.

Next, fit BR1, with its chamfered corner towards the top edge of the board. It should also have a + sign on the body of the device which you can line up with the polarity marker on the PCB. The three 1000µF capacitors can go in next, being careful to ensure that the longer (+) lead goes through the pad marked + in each case.

Now install LED1 and LED2. If you want these to be visible through the panel label on the lid of the box, fit them with the bottom of each lens 21mm above the top surface of the PCB.

However, these are really only necessary for diagnostic purposes so you could just solder them flat on the PCB like the others. As before, the cathode side (shorter lead) is indicated in the overlay with a "K" and this should line up with the flat side of the lens.

The main PCB is now complete and you can move on to building the hand controller.

Hand controller assembly

There aren't many components on this board. First solder the three small resistors in place, then fit the RJ12 connector in the same manner as you did for the main board. Having done that, solder S1 and VR3 in place after making sure they have been pushed down fully onto the PCB.

For VR2, you can use a similar pot to VR3 however it's better if you use the 16mm pot with centre detent, as specified in the parts list. In this case, the pot is be mounted on the case and attached to the PCB via three short (~50mm) flying leads. Refer to the photo above to see how the wiring is done.

Completing the hand controller

The next step is to prepare the two cases to accept the boards. For the hand controller, this is simply a matter of drilling three holes in the lid for the two pots and pushbutton shaft to poke through.

You can download the panel label artwork from the SILICON CHIP website and use this as a drilling template; or copy Fig.10. The hole for the 9mm pot should be drilled to 7mm and 8mm for the 16mm potentiometer. Ideally, you should also drill a 3mm hole for the latter pot's locking tab, although you can simply snap this off (but then you will need to do its nut up tight to stop it rotating).

Having done that, print and affix the panel label (see the link below Fig.10 for suggestions on how to do this) and cut out the holes with a sharp hobby knife; there's no need to make a hole for the pot's locking tab as this will not protrude through the case.

Now cut and/or file a rectangular hole in the case end panel, as shown in Fig.10. You can then insert this into the appropriate slots and affix the hand controller PCB to the integral posts in the bottom of the case using four small self-tapping screws. Note though that you need to place two M3 Nylon nuts on top of each of these posts before inserting the screws; these act as spacers to get the modular socket to the right height.

It's then simply a matter of inserting the other end panel into the case, placing the lid on top, using the four supplied screws to join the two halves of the case together and then attach the two knobs and the button cap for S1. The knob for VR3 and the button cap for S1 are simply pressed on and held by friction while you will need to use the grub screw to attach the knob for VR2.

Completing the main unit

Now to complete the main unit. First, you need to cut or file down the rim around the lid of the case so that when you attach the PCB later, the part which projects out the side will not be fouled by this rim. See the photo adjacent to Fig.9 for details.

Having done that, the next step is to make the cut-out for the modular socket in the side of the case. Fig.9 shows the detail. The only remaining holes that need to be made are for LED1 & LED2, assuming you've decided to install them with long leads so that they can be seen with the lid on. The positions for these 3mm holes are shown in Fig.9.

Now affix the panel label, using the same technique as for the hand controller, making sure the "Motor Drive Present" text goes just below the two holes if you have drilled them. The label should be orientated so that the logo is near the cut-out for the modular socket.

Then attach the PCB to the lid using two short self-tapping screws and check that the two halves of the case fit together properly and top of the LED lenses poke through the hole (if you've made them).

But before you actually put the case together, we need to do some testing and adjustment.

Test & set up

Plug the hand controller into the main board using a 4-wire telephone cable and centre the speed pot while the inertia pot should be fully anti-clockwise. Adjust trimpot VR1 on the main board to be fully clockwise.

Apply power to the main board via CON1 or CON2 and check that LED3 lights. The other LEDs should be off. If any of the other LEDs light up, switch off and check for faults. Using IC3's ground plane as the 0V reference, check for 4.5-5.5V at the V_{CC} test point and half that at the $V_{CC}/2$ test point. If you have a frequency meter, measure the frequency at the SYNC test point. It should be in the range of 8-10kHz.

Measure the AC voltage across the terminals of CON3. You should get 0V. Now slowly rotate VR1 anti-clockwise

Parts List

1 double-sided PCB coded 09103171, 143.5 x 50.5mm
1 flange mount ABS box, 125 x 80 x 35mm (Altronics H0121)
1 panel label, 50 x 92mm
1 20kΩ single-turn horizontal PCB-mount trimpot (VR1)
2 No.4 x 5mm self-tapping screws
2 2-way 6.35mm PCB-mount terminal blocks (CON1,CON3) (Altronics P2036A)
1 PCB-mount DC socket, 2.1mm or 2.5mm ID (CON2)
1 6P4C RJ14 low-profile PCB-mount modular socket (CON4) (Altronics P1432)
2 14-pin DIL sockets (optional)
10 PCB stakes (optional)

Semiconductors
1 TL074 quad JFET-input op amp (IC1)
1 MC14584 hex schmitt trigger inverter (IC2)
1 DRV8871 H-bridge IC (IC3)
1 78L05 100mA 5V linear regulator (REG1)
1 400V 4/6A vertical PCB-mount bridge rectifier (BR1) (Jaycar ZR1360, Altronics Z0076)
2 3mm yellow LEDs (LED1,LED2)
1 3mm red LED (LED3)
2 3mm green LEDs (LED4,LED5)

Capacitors
3 1000µF 25V low-ESR electrolytic capacitors
1 10µF 6V tag tantalum capacitor
2 2.2µF 50V multi-layer ceramic capacitors
2 1µF 50V multi-layer ceramic capacitors
1 1µF 25V X7R SMD ceramic capacitor, 2012/0805 size
2 100nF 50V multi-layer ceramic capacitors
1 10nF 50V MKT capacitor

Resistors (all 0.25W, 1%)

2 10MΩ	2 47kΩ	1 22kΩ	1 18kΩ	1 10kΩ
1 3.3kΩ	3 2.2kΩ	1 1kΩ	3 220Ω	

Additional parts for hand controller

1 PCB coded 09103172, 98 x 40.5mm
1 light grey ABS instrument case, 160 x 60 x 30mm (Altronics H0216)
1 panel label, 51 x 94mm
1 6P4C RJ14 low-profile PCB-mount modular socket (CON5) (Altronics P1432)
1 PCB-mount tactile switch with 22mm long actuator (S1) (Altronics S1119)
1 100kΩ 16mm potentiometer with centre detent (VR2) (Futurlec 100KBDETENT)
1 1MΩ 9mm vertical PCB-mount potentiometer (VR3) (Altronics R1950)
1 button cap (for S1) (Altronics S1482)
1 33mm black 1/4" shaft knob with white marker (for VR2) (Altronics H6067)
1 11mm black 18 tooth spline plastic knob (for VR3) (Altronics H6545/6)
4 No.4 x 5mm self-tapping screws
8 M3 Nylon hex nuts
3 50mm lengths of light duty hookup wire
1 2m RJ14 to RJ14 telephone cable (eg, Altronics P0766)

Resistors (all 0.25W, 1%)

1 56kΩ	1 47kΩ	1 10kΩ

until LED1 and/or LED2 light up, then back off slightly until both LED1 and LED2 are off. Check again that you have 0V at CON3.

You can now slowly rotate speed pot VR2 in one direction. If rotating clockwise, LED1 and LED4 should both light up and get brighter as you turn the pot further. If rotating anti-clockwise, LED2 and LED5 should both light up and get brighter as you turn the pot further.

Now rotate the inertia pot clockwise and the above should still hold true but you should notice that the rate of change of LED brightness has been reduced. With the speed pot fully at one stop, hold down brake switch S1 and check that LED1, LED2, LED4 and LED5 all switch off in fairly short order and return to their previous states once you release it.

As a final test, you can hook up the CON3 terminals to a pair of train tracks and check that you can control the speed and direction of a locomotive on those tracks as expected. If it moves in the opposite direction to what you intend, simply swap the connections at CON3.

Final assembly and usage

Now that you've confirmed it's working, you can join the two halves of the box with the supplied screws and integrate the controller into your layout.

Note that while pressing and holding the brake button will bring everything to a halt very quickly, practice will allow you to tap S1 to slow a locomotive, which will return to set speed when you release it.

If you do need to use S1 for emergency braking, remember to set speed potentiometer VR2 to its central position (easy if you've used a pot with centre detent) before releasing S1 in order to prevent the locomotive from moving again when S1 is released.

RJ12 adaptors can be purchased and placed along a loom cabled around the layout so that the hand control can be unplugged and moved to a different location as you operate.

The speed set at the time of unplugging will be maintained for a period and will slowly diminish over time until control is re-established, which might cause a rapid return to the former speed. It's best to set the inertia control fairly high before plugging the controller back in to avoid this. SC

Fun with Cheap PV (Solar) Cells

by ROSS TESTER

We've often looked at the small PV panels now being used on and in products ranging from garden lights and decorations to self-powered instruments and thought "they'd be handy if you could get them cheap!" Now you can – and the uses are, if you'll pardon the cliché, limited only by your imagination.

I have to admit that immediately after Christmas I bought a couple of sets of "solar powered" Christmas lights – not because I wanted yet more Christmas tree lights but because they were so incredibly cheap and because I thought I could do something else with them.

I knew that each of these panels contained a small PV (photo-voltaic) cell along with a small rechargeable battery, in most cases a "AA" NiMH. They're the bits I wanted and as a bonus for my couple of dollars I received a couple of hundred (OK, 500!) coloured LEDs connected in various strings and a tiny microcontroller board which drove them.

I'm not sure if I can do anything with the LEDs and controller except put 'em up next Christmas for my contribution to National Lampoon's Christmas Vacation. Maybe over the next nine months or so some experimentation might uncover something. But that PV cell and battery, well, they're another matter.

Just in case you've been hiding in outer Mongolia (no wait, that's probably where the Christmas lights are made...) the theory is that the PV cell provides current to charge the battery while the Sun shines. At night (which, of course, the microcontroller knows because there is no PV cell current) it turns on and starts controlling the string(s) of LEDs in a range of intricate patterns.

We're not sure exactly how this works but it's a fair bet that each LED, or each string of LEDs, has its own chip which the micro can address – hence the pretty patterns. At sunrise or when the battery is flat, whichever comes first (and it's more likely the latter), the LEDs turn off, ready to go through the next 24-hour cycle.

And the amazing thing is that you can get all this for less than twenty dollars (or if you wait like I did, a tiny fraction of that price).

The fact that they are made to a price is evident by the fact that often these lights don't last long. Whether it's battery failure, PV cell failure or micro failure, they often

Two PV cells are available. The larger of the two (above) is 90 x 63mm and produces up to 5V @ 120mA. . .

. . . while the smaller is 85 x 50mm and is capable of up to 5V @ 80mA. The dollar coin gives you a scale reference.

don't last the full Christmas period. To prove the point, I connected the one of the failed systems to a low-voltage DC power source and . . . presto, they worked!

Oatley's cheap PV cells

After going to all the trouble of buying discounted lights just for the PV cells and batteries, you can imagine my chagrin when Oatley Electronics told us of some really special offers in PV cells in early January!

How special? Packs of thirty 5V, 80mA solar panels for $16.00 including a schottky diode (we'll explain its purpose in a moment). Or perhaps even better – a pack of 20 slightly larger cells (5V @ 120mA) for $20.00!

Do the maths: 30 x 80mA or 20 x 120mA equals 2.4A @ 5V or 12W – an extremely useful amount of power, suitable for a whole range of applications (and we'll get to a few of these shortly). Of course, that's in full, direct sunlight. Early morning or late afternoon sunlight will see this taper off.

Incidentally, if you measure the open-circuit voltage in full Sun, you would get close to 6V but when you start to draw power, the voltage drops. 5V is the "sweet spot" for maximum efficiency.

What to do with them?

Quite a number of applications spring to mind:

Charging batteries – either mobile phone batteries (believe it or not, their original use) or connected in series/parallel for a range of other voltages.

Phone supply – use the USB socket on your phone, notebook, etc with parallel-connected cells to power your gear while away from a mains power source. Sorry, iphone users – Apple has done away with the USB socket!

Solar skylight – do you have a dark room in the house? Put some of these on the roof and a suitable LED in the room and you'll be surprised at how much light you'll get during the day.

Battery-backed solar skylight – combine both of the above with a suitable battery and you'll have a light that can be used at night as well as during the day.

Remote control garage door/gate supply – if it's inconvenient to run mains power to your garage door controller, power it from a small 12V SLA battery, kept charged by these solar panels. For example, see the articles in April & May 1998 and October 2004.

Under-floor ventilation – keep the air circulating under the house to prevent mildew and damp with a suitable fan, exhausting to outside, connected to the cells. It won't cost you anything to run, either. The same idea can be used for a room that's always smells "musty" when closed up.

Car internal cooler – use the same idea as above to exhaust hot air from your car while it's parked during the day. Costs nothing to run – and will actually save you money because the air conditioner won't have to work so hard.

Unattended boat keeper – a few cells on the deck of the boat can help keep alarms etc, in operation while you're not there.

Camping supply – use the solar cells to keep the tent air circulating, or to provide light at night via a rechargeable torch, etc. Or perhaps to keep your phone charged the other side of Woop Woop.

Prawn lure – combine some LEDs, a battery and solar cells in a waterproof glass jar and make yourself a convenient prawn lure. yourself a convenient prawn lure.

OK, how do we mount them?

Oatley Electronics have come up with a rather unusual method of mounting: silicone sealant and gutter guard! Sure, you could make up a frame of some sort to hold them but they're already coated with a clear epoxy resin on front,

Ten cells are powering four x 3-LED arrays in parallel, merely from the modelling light in our studio flash. In sunlight, they're much brighter! Note the rudimentary heat-sink the LEDs are mounted on.

and the PCB has a conformal coating to protect it.

The only bits of the PCB that aren't protected are where you solder your connecting wires, and we think it would be wise to cover these (after soldering!) with some silicone sealant or even some spray-can conformal coating such as Electrolube Flexible Silicone Coating (**www.electrolube.com.au/products/conformal-coatings.html**).

If you don't cover the copper and use the PV cells outside, the copper would quite quickly corrode, leading to premature cell failure.

We've shown a couple of photos of the cells mounted on gutter guard – it has the big advantage of being very flexible and it is also cheap! Add a tube of silicone sealant from your friendly hardware store and that's it. You can even nail or screw the gutter guard onto an appropriate (sun-lit) surface.

You could even glue the panels to the gutter guard and solder your connecting wires later, as long as you're careful with the sealant placement.

Wiring

This depends entirely on the use you're putting the PV cells to. They can be wired in series for higher voltage - for example, to keep a 12V battery "float charged" you'd want three in series (~15V); to provide a higher rate of charge, you'll need to parallel several sets of three cells.

We'll look at some examples in a moment.

The schottky diode

PV cells have the unfortunate "feature" of allowing current to flow through themselves when dark, so if left wired to a battery, all the good charging done during the day can be lost at night, as the battery discharges via the cells. But the simple method of wiring a diode in series with the positive line (anode to the cells, cathode towards the battery) prevents this.

While the cell is producing power, the diode will be forward-biased (ie, the anode voltage is higher than the cathode), so charging current can flow to the battery. But when the cell is in the dark, the cathode has a higher voltage than the anode, so it is reverse-biased, thus preventing self-discharge.

It's a bit different – but it's dirt cheap and works well! A roll of "Gutter Guard" (8m roll $2.90 at Mitre 10) and a tube of silicone sealant (~$4 just about anywhere!) and you have a flexible mounting system for your PV cells. Note our comments about covering over the bare copper on the PCB with a conformal coating (or even silicone sealant).

But you can't just use any old diode because you'll lose too much power. All diodes have a forward voltage between anode and cathode – and that is voltage that you cannot use; it is lost. A normal silicon diode has a forward voltage of about 600-700mV which, when the PV cell is only producing 5V at its maximum output, is rather too much to lose!

By contrast, a schottky diode has a forward voltage of only about 200mV, so you're not going to waste too much of that precious energy you went to all the trouble to produce from the PV cell. In fact, with a silicon diode, the panel would struggle to charge a lot of battery types at 4.3V (5V – 0.7V); at 4.8V, it has a much better chance.

Let's look at some specific ideas

The ideas mentioned above are all practical and possible – even if you don't use them exactly, they may start your creative juices flowing for that project you've been thinking about.

(1) Phone battery charger

This is the simplest application that we can think of – it all depends on what you want to charge. mobile phone charger. As we mentioned earlier, this sort of PV cell was originally intended for charging mobile phone batteries.

These days, most mobile phone batteries are nominally 3.7V. In almost all cases, the USB/microUSB socket connects to the input of a charge controller IC designed to operate over the range from 4.5-5.5V, so directly connecting one of these cells (or a few in parallel) to the USB socket is permissible.

You might have to sacrifice a surplus micro USB lead to be able to plug into the phone – it's not real easy to buy micro USB plugs. If you can find one, Fig.1 shows the two connections required on the plug. Otherwise, cut the USB A plug off the lead, identify the two wires (+ & -, normally red and black) you need with a multimeter and solder these to the PV cell positive and negative terminals.

(2) Larger battery chargers

To charge a 6V battery, you need two cells in series. That gives 10V; arguably a little more than needed but once again, power is limited so there's nothing much to worry about.

To charge a 12V battery, six cells in series/parallel would be the go – two lots of three cells in series, giving 15V (see Fig.2).

You could trickle-charge an 18V or even a 24V battery in a similar way – two parallel strings of four or five cells for 18V; two parallel strings of six for 24V. In all cases, include the schottky diode.

(3) Solar skylight

The number of cells needed is directly proportional to the power of the LED(s) used. For a 20W (or 33W) LED, two parallel strings of seven cells would be used (see Fig.3).

If the LEDs are the smaller 10W types two parallel strings

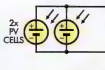


Fig.1: here's how to keep your mobile phone battery charged away from power. You'll need a micro-USB plug to connect it (pinout shown at left).

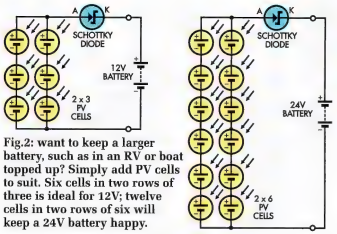


Fig.2: want to keep a larger battery, such as in an RV or boat topped up? Simply add PV cells to suit. Six cells in two rows of three is ideal for 12V; twelve cells in two rows of six will keep a 24V battery happy.

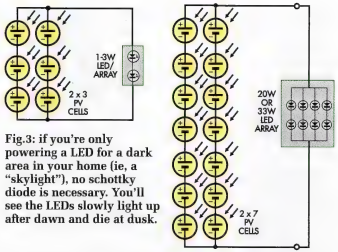


Fig.3: if you're only powering a LED for a dark area in your home (ie, a "skylight"), no schottky diode is necessary. You'll see the LEDs slowly light up after dawn and die at dusk.

of five cells are more than adequate. Note that the LEDs should be mounted on some form of heatsink – you don't need much, as our photo of the 10W string shows. You can connect up to four of these LEDs in parallel.

(4) Solar skylight with battery

If you want the convenience of charging a battery (eg, an SLA) at the same time as lighting LEDs (ie, for night and day use), you will need to add at least one more series string of cells in parallel with the others.

In this case, the schottky diode will be required and you'll want some form of on/off switch in series with the LEDs. Turning them off when not required will also allow faster and/or deeper charging of the battery.

(5) Garage door remote control supply

One problem with garage door and gate remote controls is that they're often mounted in a place without access to power.

You can solve that problem by connecting some PV cells to a battery in the same way as above and run without AC power.

This is not intended to power the door/gate motor itself, just the remote control receiver. So you only need a small capacity battery, usually 12V. But the smallest size you can buy should be fine as the remote control is very intermittently used and in most cases, only requires a relay to pull in for a short time or even a transistor to switch on briefly.

We know someone who did this several years ago (when small solar panels first came out) and the controller is still running quite happily.

(6) Under-floor air circulation

Many people unwittingly block air vents under their homes. A garden bed or path positioned against the wall is a common mistake.

The result is that the air under the house cannot vent or circulate and ends up smelling foul. If the ground under the house is at all moist, the problem is exacerbated. It's that "musty" smell that suggests mould or similar is thriving.

If you fit a small "muffin" fan into the brickwork, a PV cell can drive it during the day and extract that air to the outside, so it continuously circulates.

All you need are enough panels – a 12V fan will usually operate quite happily (albeit a bit slower) at 10V but will not be upset with 15V – so two or three panels in series would be ideal. These fans are quite efficient so you may only need one set of panels but larger fans will require more power.

So once again, a series/parallel arrangement would suffice. Since batteries are not involved, no schottky diode would be required in this application.

(7) Car cooler

A similar arrangement can be set up to extract hot air from your car when it's in the Sun. You can buy some commercial units which operate from the car battery but using a solar panel and a small fan will mean you'll never return to a cool car which won't start!

You'll need some ingenuity in making a suitable mounting bracket for this one – commercial units sit in a slightly open window but make sure you don't sacrifice car security for comfort!

(8) Boat, caravan, mobile home battery keeper

Because a lot of craft or vans are used on a very intermittent basis, you have to ensure that their house batteries are kept charged. Allowing a battery, particularly a lead-acid type, to flatten will almost certainly end up with tears!

You could mount as many cells as you need on the boat deck or van roof, wired directly to the battery. The number will depend a lot on the size of your house battery – three cells producing 15V @ 120mA are better than nothing, but not much better.

You probably need a good 500mA to 1A trickle-charge to keep the battery voltage up, particularly if it also powers things like intruder alarms, anchor light etc. Don't forget the schottky diode to prevent night-time discharge.

(9) Camping supply

Whether you're after light, a mobile phone/computer charger, or even a fan on stifling hot summer nights, you can use the techniques above. Charging your phone doesn't

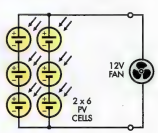
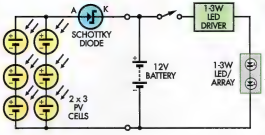
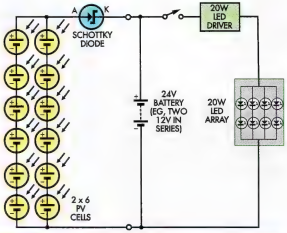


Fig.4: to extract musty air from under your house, a high-efficiency fan can be left connected 24/7 – naturally it will only work during daylight hours. The circuit is virtually identical to the 12V skylight circuit.



If you want to charge a battery for night-time use as well, you'll need both a schottky diode and a suitable LED driver (you cannot connect the LEDs directly to the battery or the light output will be rather brief. Bright, but brief!)



take much (probably just one PV cell). Your computer may well need several, depending on the battery voltage. And charging a battery for night-time use is much the same – the larger capacity battery, the more cells you're going to need.

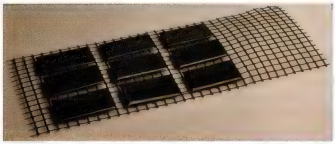
Just remember to keep the PV cells in direct Sun during the day (often the tent is erected in shade!).

(10) Prawn/fish lure

Because today's LEDs are so bright and so efficient, it doesn't take much battery power to run them for quite a long time. With a suitable (waterproof) clear container you could mount as many PV cells inside as required to charge a battery, with as many white LEDs as your system will allow.

Make it completely waterproof by including a mercury "tilt" switch – when it's vertical, it turns on. And don't forget the schottky diode to stop the battery self-discharging.

Leave it in the sun all day and it will be ready for your prawning/fishing trip at night.



Here are 3 x 3 cells mounted on a short length of Gutter Guard (about 10c worth!).

Oatley Electronics special offers

To go with this feature, Oatley Electronics are offering some special deals at special prices!

(1) A pack of 30 smaller 80mA panels (45 x 90mm) plus three 1A schottky diodes: **$16.00** (Cat SP4590)
(2) A pack of 20 larger 120mA panels (60 x 90mm) plus three 1A schottky diodes: **$20.00** (Cat SP6090)

Extras – if purchased at the same time as either of the above packs:
(3) 10W LED: $1.50 each (limit of one per PV panel pack - Cat IT104)
(4) 20W LED: $2.50 each (limit of one per PV panel pack – Cat IT105)
(5) 60mm Brushless Fan: $2.00 each (limit of one per PV panel pack – Cat IT106)
(6) USB A to B lead: (note – not a micro USB lead) $1.00 each (Cat IT107)

Contact:

Oatley Electronics, PO Box 139, Ettalong Beach NSW 2257
web: www.oatleyelectronics.com.au;
email: sales@oatleyelectronics.com.au)
Phone: 0490 347 297 (best to send an SMS requesting a callback)

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Like the Relay Module, this MOSFET module is single-direction, but provides speed control through a PWM signal (think of it as turning the motor off and on very fast). This module can control 5A at 24VDC.

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Has eight outputs to control up to four DC Motors or two Stepper Motors. Being in a Shield configuration makes it easy to connect to a main board.

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Has four outputs for controlling two DC Motors or one Stepper Motor, and can be configured with jumper leads to run off any of the Arduino pins. It can provide 4A at up to 30V, and has an onboard 5V regulator to power the Arduino Main Board.

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Sports eight outputs (for four DC motors or two Stepper Motors), and a DC jack, power switch and regulator to provide all power control needs. Each output can provide 1A at 5-16V, and there are both screw terminal connections (for DC motors) and socket headers (to suit some Stepper Motors).

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To control a motor backwards and forwards without speed control, use either our 4 Way (XC-4440) or 8 Way (XC-4418) Relay Modules. They've plenty of power (up to 10A at 30VDC), but need a separate 12VDC power supply to operate the relays. They provide isolation between the Arduino® circuit and switched circuit.

4 CHANNEL XC-4440 **$12.95**
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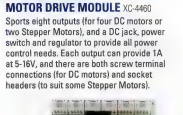
DUAL MOTOR DRIVER SHIELD

XC-4264

Four outputs for controlling two DC Motors or one Stepper Motor, and can supply up to 2A at 8-40V per output. The shield has screw terminals for feeding power in, and also has adjustable current limiting switches.



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DUAL MOTOR SHIELD XC-4556

This is a similar unit to XC-4492, but in a shield- handles two DC Motors or one Stepper Motor at 2A up to 15V. This shield also has power-in screw terminals and a 5V regulator for supplying the Arduino® Main Board.

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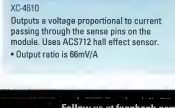

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30A CURRENT SENSOR MODULE

XC-4610

Outputs a voltage proportional to current passing through the sense pins on the module. Uses ACS712 hall effect sensor.

- Output ratio is 66mV/A

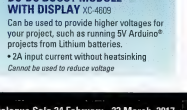
$9.95

BREADBOARD POWER MODULE

XC-4606

Receiving power from a USB socket or DC socket, this module adds a compact power supply to your breadboard.

- Plugs straight into most breadboards



$19.95

DC-DC BOOST MODULE WITH DISPLAY XC-4609

Can be used to provide higher voltages for your project, such as running 5V Arduino® projects from Lithium batteries.

- 2A input current without heatsinking

Cannot be used to reduce voltage

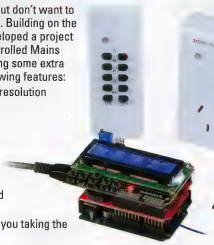
ARDUINO® PROJECT OF THE MONTH

RTC POWER POINT TIMER

Using Arduino to control a 240V appliance but don't want to get zapped? Well then, here is your solution. Building on the simplicity of the Arduino® Clock, we've developed a project that interfaces to our MS-6148 Remote Controlled Mains Outlet using a 433MHz transmitter and adding some extra code, gives you a mains timer with the following features:

- Switch on/off appliances with a minute of resolution
- Keeps time during power off
- Programme up to 99 timers
- Can be set for any or all days of the week, weekdays or weekends
- Can be set to turn single channel or all channels on or off
- Manual control of transmitter for setup and troubleshooting

And being Arduino®, there's nothing to stop you taking the code apart and adding your own features.

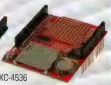


Finished project

DIY

MORE INFO ONLINE

XC-4410



XC-4536

XC-4454

ZW-3100

MS-6148

KIT VALUED AT $103.75

SEE STEP-BY-STEP INSTRUCTIONS AT www.jaycar.com.au/RTCpowerpointtimer

NERD PERKS CLUB OFFER

BUY ALL FOR $79.95

SAVE OVER 20%

WHAT YOU WILL NEED:

UNO MAIN BOARD	XC-4410	$29.95
DATA LOGGING SHIELD	XC-4536	$19.95
LCD SHIELD	XC-4454	$19.95
WIRELESS 433MHZ TRANSMITTER MODULE	ZW-3100	$13.95
REMOTE CONTROLLED MAINS OUTLET	MS-6148	$19.95

SEE OTHER PROJECTS AT www.jaycar.com.au/arduino

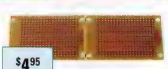
ARDUINO® ESSENTIALS

$5.95 ea

150MM JUMPER LEADS - 40 PIECE WC-6024

A pack of 40 jumper leads of various colours for prototyping. Ideal for Arduino® and DIY projects. Each flexible lead is 150mm long with pins to suit breadboards or PCB headers

PLUG TO PLUG WC-6024 **$5.95**
SOCKET TO SOCKET WC-6026 **$5.95**
PLUG TO SOCKET WC-6028 **$5.95**

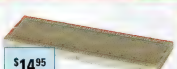


$4.95

ULTRA MINI EXPERIMENTERS BOARD HP-9556

20 x 16 holes with links and strips (bus rails) every 2 holes. Supplied as a pair, end- to-end. Can be snapped apart to make two boards.

- 130 x 45mm



$14.95

BREADBOARD WITH 830 TIE POINTS PB-8815

Ideal for electronic prototyping and Arduino® projects. labelled rows and columns. Adhesive back for mounting.

- 830 Tie points
- 200 Distribution holes
- 165(L) x 54(W) x 9(H)mm

$18.95

32 PIECE PRECISION DRIVER SET TD-2106

Ideal for jewellery, model making or electronics. Tactile handle with extendable hardened shaft. Slotted, Phillips, Pozidriv, Torx and Hex pieces.

$49.95

DUINOTECH MEGA XC-4420

Our most powerful Arduino® compatible board. Boasting more I/O pins, more memory, more PWM outputs, more analogue inputs and more serial ports.

- 256KB program memory
- ATMega2560 Microcontroller
- 108(W) x 53(L) x 15(H)mm

BASIC EXPERIMENTER KIT XC-4285

For the Arduino® beginner. Each kit contains a duinotech board, a breadboard, jumper wires and a plethora of peripherals. Each kit comes in a plastic organiser.

$79.95

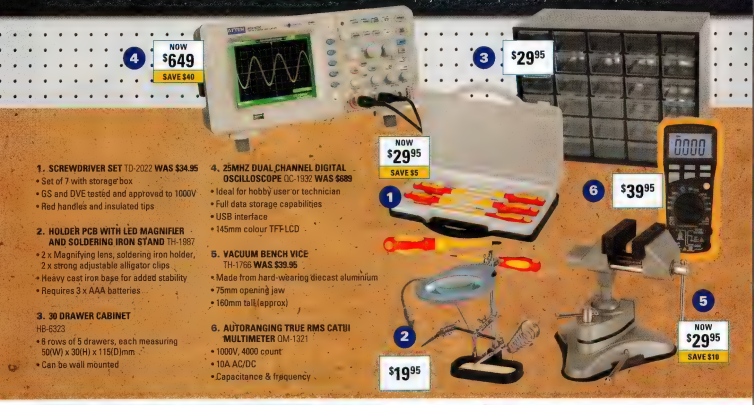
$29.95

STAINLESS STEEL CUTTER PLIERS TH-1812

Set of five 115mm cutters and pliers for electronics, hobbies, beading or other crafts. Soft ergonomic grips.

WORKBENCH TOOLS FOR YOUR POWER PROJECTS

There has been an obvious resurgence in people getting back to the workbench and reviving skills involving manual dexterity. As you will see across the following pages, Jaycar has all the DIY tools you'll need to equip your workbench so you can create projects from the power of your brain and your hands.



4 NOW $649 SAVE $40

1. SCREWDRIVER SET TD-2022 **WAS $34.95**
- Set of 7 with storage box
- GS and DVE tested and approved to 1000V
- Red handles and insulated tips

2. HOLDER PCB WITH LED MAGNIFIER AND SOLDERING IRON STAND TH-1867
- 2 x Magnifying lens, soldering iron holder, 2 x strong adjustable alligator clips
- Heavy cast iron base for added stability
- Requires 3 x AAA batteries

3. 30 DRAWER CABINET
HB-6323
- 6 rows of 5 drawers, each measuring 50(W) x 30(H) x 115(D)mm
- Can be wall mounted

4. 25MHZ DUAL CHANNEL DIGITAL OSCILLOSCOPE QC-1932 **WAS $689**
- Ideal for hobby user or technician
- Full data storage capabilities
- USB interface
- 145mm colour TFT-LCD

5. VACUUM BENCH VICE TH-1766 **WAS $39.95**
- Made from hard-wearing diecast aluminium
- 75mm opening jaw
- 160mm tall (approx)

6. AUTORANGING TRUE RMS CATIII MULTIMETER QM-1321
- 1000V, 4000 count
- 10A AC/DC
- Capacitance & frequency

3 $29.95

NOW $29.95 SAVE $5

1

2 $19.95

6 $39.95

5 NOW $29.95 SAVE $10

5 WAY CRIMPING TOOL TH-1828
Cuts and strips wire. Can also cut bolts with diameter M2.6, M3.0, M3.5, M4.0 & M5.0.

$8.95 NERD PERKS 2x POINTS

PRECISION ANGLED SIDE CUTTERS TH-1897
Easily cut leads. Ideal for fine PCB work. Made from quality tool steel and have soft padded handles that are spring loaded for comfortable long term use.

$12.95 NERD PERKS 2x POINTS

NIBBLING TOOL TH-1768
Will cut any shape out of aluminium, plastic, copper and other unhardened metals up to 18 gauge.

$14.95 NERD PERKS 2x POINTS

STAINLESS STEEL WIRE STRIPPER / CUTTER / PLIERS TH-1841
Strips stranded wire from 12-24 AWG and solid wire from 10-22 AWG. Cuts wire up to 3.0mm. Spring-loaded with locking jaws, rubber handles for comfort.

$15.95 NERD PERKS 2x POINTS

$24.95

100 PIECE DRIVER BIT SET TD-2038
Magnetic holder, adaptor, Phillips bits, slotted bits, torx, tamperproof, pin drive, wing nut driver etc. Suits standard 1/4 inch driver handle. *Hex driver sold separately TD-2032 $6.95*

$29.95

30 PIECE TOOL KIT TD-2166
Minor DIY repairs are a breeze with this 30 piece tool kit. The tools are held securely in a zip-up case.

$39.95

35 PIECE MULTI-PURPOSE PRECISION TOOL KIT TD-2117
Ideal for electronics service trades and hobbyists. 30 bits, two cutters, two pliers and a flexible shaft adaptor packed in a storage case.

$49.95

ELECTRIC SCREWDRIVER SET
TD-2491
Powerful high torque electric driver and an array of stainless steel bits that will get the job done. Tough aluminium carry case containing your screwdriver, mains, charger and all the bits.

WORKBENCH POWER SOLUTION

FREE DIGITAL MULTIMETER*
Valid with purchase of MP-3079, MP-3800, MP-3840 & MP-3090
QM-1529 VALUED AT $24.95

Our range of highly efficient and reliable benchtop power supplies are specially selected to suit your unique testing and servicing applications. They use proven technology and are designed to give long service life in workshop situations. Features include low noise, low ripple and protection against overload and short circuit. Available in fixed or variable voltages. The most cost effective solution for your laboratory use, electronic and communications equipment maintenance.

$69.95 MP-3079

$149 MP-3800

$179 MP-3840

$379 MP-3090

	MP-3079	MP-3800	MP-3840	MP-3090
Features	Fixed output voltage, also available in 20A & 40A models	Compact size, high current and variable output.	Digital control & a large easy to read LED display. Over-current & short circuit protection are built-in.	High powered, variable or fixed output voltage.
Output Voltage	13.8VDC	0-24VDC	0-30VDC	3-15VDC
Output Current	12A	17A	5A	40A
Display	-	Analogue Meter (backlit) screen	LED screen	LED screen
Size (W) X (D) X (H)	170 x 160 x 85mm	148 x 162 x 62mm	110 x 158 x 280mm	220 x 110 x 300mm

SWITCHMODE PLUGPACKS WITH USB OUTLET

Slim in size, lightweight, and feature manually selectable variable voltage outputs.

- Supplied with 7 plugs and a USB output socket
- MEPS compliant

3-12VDC 600MA MP-3310 **$19.95**
3-12VDC 1.0A MP-3312 **$24.95**
3-12VDC 1.5A MP-3314 **$29.95**
3-12VDC 2.25A MP-3316 **$34.95**
9-24VDC 1-1.5A MP-3318 **$34.95**

FROM $19.95

15W SLIM POWER SUPPLIES

Regulated output voltage, small size and higher power output make these AC adaptors suitable for thousands of different applications.

- Fit side-by-side on a powerboard
- Supplied with 7 plugs
- MEPS compliant

5VDC 3.0A MP-3480
6VDC 2.2A MP-3482
9VDC 1.7A MP-3484
12VDC 1.5A MP-3486

$24.95 ea

7-PLUG DC WIRING KIT

RP-1980

Configure your own plugpacks or wire to projects to give standard DC output plugs. 1.8m.

$8.95

60W DESKTOP POWER SUPPLIES

Versatile switchmode power supplies in a range of different configurations.

12VDC 5A MP-3242 **$59.95**
19VDC 3.42A MP-3246 **$59.95**
24VDC 2.7A MP-3248 **$59.95**
12VDC 5A WITH 5 PLUGS MP-3243 **$64.95**

FROM $59.95

25¢/m

FLEXIBLE LIGHT DUTY POWER CABLES

WH-3010 - WH-3017
$0.25/m or $15/100m roll

PVC insulation. General purpose wiring. 13x 0.12mm. 0.6A rated current.

FROM 55¢/m

GENERAL PURPOSE POWER CABLES

PVC insulation. 250V wiring.
7.5A 24 x 0.2mm. WH-3040 - WH-3042 **$0.55/m or $42/100m roll**
10A 32 x 0.2 mm. WH-3050 - WH-3052 **$0.80/m or $72/100m roll**

FROM $1.25/m

AC MAINS CABLES

240V power flex fig.8 wire.
TWO CORE 7.5A WB-1560 **$1.25/m or $99/100m roll**
THREE CORE 10A WB-1562 **$2.85/m or $229/100m roll**

FROM $4.95/m

SOLAR PV POWER CABLE

Dust, age and UV resistant. Tinned copper conductors to minimise corrosion.

- 1000VDC rated voltage
- IP65 rated

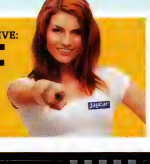
58A WH-3121 **$4.95 or $435/100m roll**
76A WH-3122 **$7.95 or $695/100m roll**

NERD PERKS CLUB MEMBERS RECEIVE:

15% OFF

ALL GENERAL PURPOSE, SOLAR & AC MAINS POWER CABLES*

*(*Applies to cables listed above or categories 3530, 353C & 3530).*



1 2 3 4 5 6 7

NERD PERKS

EARN A POINT FOR EVERY DOLLAR SPENT AT ANY JAYCAR COMPANY STORE* & BE REWARDED WITH A $25 JAYCOINS GIFT CARD ONCE YOU REACH 500 POINTS!

*Conditions apply. See website for T&Cs

REGISTER ONLINE TODAY BY VISITING:
www.jaycar.com.au/nerdperks

12/24V 20A DC TO DC BATTERY CHARGER MB-3684

$279

Dual battery system. Ideal for 12V auxiliary battery charging. Wide input range (9-32VDC) so you can charge your 12V battery from a 24V system.

- Reverse polarity
- Overload protection
- 180(W) x 134(H) x 60(D)mm

12V AGM DEEP CYCLE BATTERIES

FROM $269

Store large amounts of energy. Superior deep cycling performance for many different recreational and industrial applications such as camping, boats, motorhomes etc.

75AH 20KG WEIGHT SB-1680 **$269**
100AH 28KG WEIGHT SB-1682 **$329**

PORTABLE BATTERY BOX WITH VOLTMETER

HB-8500

$109

Designed to fit a 100Ah deep cycle battery. LED voltmeter, two high current cigarette power sockets, and bolt terminals.

140A DUAL BATTERY ISOLATOR KIT WITH WIRING MB-3686

$159

Allows two batteries to be charged from your engine alternator at the same time. Suitable for 12VDC Marine, 4WD, caravan and solar applications.

- Emergency override feature
- LED status indicator

BATTERY ISOLATION SWITCHES

High current rated battery isolation switches for high power applications. They feature high quality construction with huge bolt down terminals for electrical connection.

HIGH QUALITY 12V 120A
SF-2245 **$17.95**
PROFESSIONAL 12V 500A
SF-2247 **$59.95**

FROM $17.95

LEAD ACID BATTERY CONDITIONER NA-1420

$10.95

Removes or reduces sulphation. One bottle will do up to a N70Z size battery (4WD, boat, truck, etc.)

- 92ml

UNIVERSAL BRASS BATTERY TERMINALS

Heavy duty, solderless, marine grade brass battery terminals perfect for isolating your battery to prevent battery drain when not in use. Sold in pairs.

SADDLE HC-4030
LUG BOLT STYLE
HC-4034

$9.95 pr

TECH TIP

MAXIMUM POWER POINT TRACKING (MPPT)

Maximum power point tracking (MPPT) controllers use a DC to DC switchmode power converter to give the best solar system efficiency. The intelligent circuitry tracks the panel output and adjusts the converter to yield the maximum amount of power under widely varying solar conditions.

50A MPPT SOLAR CHARGE CONTROLLER

MP-3731

$449

A highly intelligent charge controller for use with solar installations up to 95VDC. Use with 12, 24, 36, or 48V battery banks. Maximum Power Point Tracking (MPPT) for maximum efficiency and charge rate.

- Overcharge and under-voltage, and reverse current protection
- 202(W) x 235(H) x 88(D)mm

ANDERSON® 50A HIGH CURRENT CONNECTORS

$9.95 ea

Used widely in both domestic and industry, you'll find this connector in many 4WD applications, boating, automotive and other industries. Supplied as a moulded 2 pole with contacts. 50A, 600V (AC or DC).

WITH 8 GAUGE CONTACTS PT-4425
WITH 10-12 GAUGE CONTACTS PT-4427
WITH 6 GAUGE CONTACTS PT-4420

HIGH CURRENT LEADS

FROM $14.95

A series of high current connector leads for automotive, caravan, 4WD or industrial interconnection. Easily adapt or extend your 50A Anderson connector with the following 300mm long adaptors or 5m extension.

EYE TERMINAL PT-4444 **$14.95**
15A CIGARETTE PLUG PT-4446 **$16.95**
15A CIGARETTE SOCKET PT-4448 **$16.95**
PIGGYBACK LEAD PT-4442 **$34.95**
5M EXTENSION LEAD PT-4440 **$79.95**

WATERPROOF SOLAR POWER PV CONNECTORS

$7.50 ea

IP67 rated for maximum environmental protection.

- 1000VDC rated voltage
- 30A at 70°C, 25A at 85°C rated current

4MM FEMALE INLINE PS-5100
4MM MALE INLINE PS-5102
6MM FEMALE PANEL MOUNT PS-5104
6MM MALE PANEL MOUNT PS-5106

SOLAR PANEL 'Y' LEADS

$19.95 ea

Used for connecting the output of two solar panels in parallel or connecting multiple panels in an array. Waterproof and UV resistant. 300mm.

2 SOCKET TO 1 PLUG PS-5110
2 PLUGS TO 1 SOCKET PS-5112

HEAVY DUTY CRIMP TOOL WITH QUICK INTERCHANGEABLE DIES

TH-2000 **RRP $49.95**

Uses quick interchangeable dies, no screwdriver needed. Features ratchet mechanism for maximum power and quick release. Dies sold separately.

PV CONNECTOR DIE TO SUIT TH-2000.
TH-2010 **$29.95**

NERD PERKS
BOTH FOR $59.95
SAVE $19.95

3.7V LI-ION RECHARGEABLE BATTERIES

NIPPLE CONNECTION:
14500 800MAH SB-2300 **$9.95**
18650 2600MAH SB-2308 **$19.95**
26650 3400MAH SB-2315 **$24.95**
SOLDER CONNECTION:
14500 800MAH SB-2301 **$10.95**
18650 2600MAH SB-2313 **$21.95**
26650 3400MAH SB-2319 **$25.95**

FROM $9.95

3.2V LIFEPO4 RECHARGEABLE BATTERIES

Lithium iron phosphate (LiFePO4) is a more chemically stable type of lithium rechargeable cell. Safer and longer cycle life than traditional Li-ion cells.

14500 600MAH SB-2305 **$9.95**
18650 1600MAH SB-2307 **$17.95**
26650 3000MAH SB-2317 **$24.95**

FROM $9.95

UNIVERSAL LITHIUM CYLINDER BATTERY CHARGER MB-3637

$59.95

Dual independent charging slots for charging Li-ion, Li-Po and LiFePO4 cylinder cells. Powered using the supplied mains power adaptor, 12V cigarette lighter lead, or via USB inputs. Includes an LCD to display the status of capacity, voltage, time and battery condition (poor/fail)

- Adjustable battery contacts
- Suitable for AA & AAA Ni-Cd & Ni-MH

Batteries not included.

UNIVERSAL PROGRAMMABLE BALANCED BATTERY CHARGER

MB-3632 **WAS $89.95**

NOW $79.95
SAVE $10

Charges Li-ion, Li-Po, Ni-Cd, Ni-MH and lead acid batteries. Li-Po batteries are balance-charged so there's no risk of damage or explosion from incorrect charging. Powered by mains plug pack or a 12V battery.

- LCD display
- 132(L) x 82(W) x 28(H)mm

POWER MANAGEMENT

FROM $7.95

CENTRE TAPPED TRANSFORMERS

Build your own power supply.

See website for specifications.

9V CT, 1.35VA, 150MA MM-2017 **$7.95**
24V CT, 3.6VA, 150MA MM-2018 **$8.95**
12.6V CT, 1.9VA, 150MA MM-2006 **$7.95**
30V CT, 4.5VA, 150MA MM-2007 **$8.95**

$18.95 ea

MULTI-TAPPED TRANSFORMERS

See website for specifications.

15 - 30V, 30VA, 1A MM-2008
6-14V, 30VA, 2A MM-2004

$49.95

50VA 240VAC TO 115VAC STEPDOWN TRANSFORMER

MF-1091

Includes overheat protection. When overheating, the thermal fuse will open, then close after unit cools down, restoring operation. Two pin US socket for 110V appliance and cord plug for 240V. Not for use in wet areas.

- Not dielectrically isolated
- 50W

Models up to 1000W also available. See website or instore for details.

NOW $219
SAVE $20

VARIABLE LABORATORY AUTOTRANSFOMER (VARIAC)

MP-3080 **WAS $239**

Encased in heavy-duty steel housing, this unit enables the AC input to e mains powered appliance to be easily varied between 0 to full line voltage (or greater). A must for testing mains performance.

- 500 VA (fused) rated power handling
- 0–260 VAC @ 50Hz output voltage
- 165(D) x 120(W) x 160(H)mm

INVERTERS & CONVERTERS

12VDC TO 230VAC ELECTRICALLY ISOLATED INVERTERS

Run small electrical appliances from your car battery with these modified sinewave inverters.

150W MI-5102 **$59.95**
300W MI-5104 **$79.95**
400W MI-5106 **$89.95**
600W MI-5108 **$129**

MI-5102

MI-5726

FROM $59.95

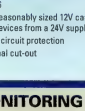
12VDC TO 230VAC PURE SINE WAVE INVERTERS

Recommended when powering sensitive electronics and motor-powered devices.

- Over & under voltage protection
- USB port

200W MI-5726 **WAS $199 NOW $179 SAVE $20**
400W MI-5728 **WAS $249 NOW $219 SAVE $30**

FROM $179
SAVE UP TO $30



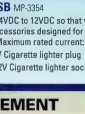
$29.95

24VDC TO 12VDC 3A CONVERTER

AA-0266

Run a reasonably sized 12V car-stereo or other devices from a 24V supply.

- Short-circuit protection
- Thermal cut-out

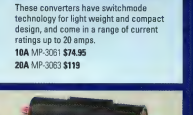


$64.95

24VDC TO 12VDC 5A CONVERTER WITH USB MP-3354

Converts 24VDC to 12VDC so that you can use car accessories designed for 12V vehicles. Maximum rated current: 5A

- Input: 24V Cigarette lighter plug
- Output: 12V Cigarette lighter socket



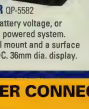
FROM $74.95

24VDC TO 12VDC CONVERTERS

These converters have switchmode technology for light weight and compact design, and come in a range of current ratings up to 20 amps.

10A MP-3061 **$74.95**
20A MP-3063 **$119**

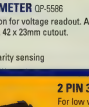
MONITORING & MEASUREMENT



$22.95

SELF-POWERED LED VOLTMETER QP-5582

Easily monitor your battery voltage, or the voltage in any DC powered system. Supplied with a panel mount and a surface mount "hood". 5-30VDC. 36mm dia. display.

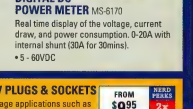


$24.95

SELF-POWERED LED PANEL METER QP-5586

2 wire connection for voltage readout. Auto zero calibration. 42 x 23mm cutout.

- 8-30VDC
- Automatic polarity sensing



$89.95

DIGITAL DC POWER METER MS-6170

Real time display of the voltage, current draw, and power consumption. 0-20A with internal shunt (30A for 30mins).

- 5 - 60VDC

12V POWER CONNECTION

MERIT CONNECTORS

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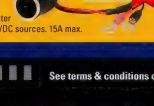

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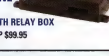

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Arrival dates of new products in this flyer were confirmed at the time of print but delays sometimes occur. Please ring your local store to check stock details. Occasionally there are discontinued items advertised on a special / lower price in this promotional flyer that has limited to nil stock in certain stores, including Jaycar Authorised Stockist. These stores may not have stock of these items and can not order or transfer stock. Savings off Original RRP. Prices and special offers are valid from Catalogue Sale 26 February - 22 March, 2017.

PRODUCT SHOWCASE

Redback Impedance Meter makes a technician's or a roadie's life so much simpler!

Measuring a transformer with a regular ohm meter or multimeter is very difficult and provides inaccurate results. That's because they use DC to measure "resistance".

But a transformer will normally have a very low DC resistance – using AC at the transformer's design frequency will give a much higher reading.

The Redback Q2003 Impedance Meter (from Altronics) does just that – and can do much more besides.

It's intended for technicians and installers of PA equipment, particularly those using 70V and 100V lines (to minimise line losses).

The Q2003 shows the impedance on a two-line LCD readout, along with 100V and 70V load values.

A 100V speaker system (most popular in Australia) will have many speakers, all with their own line transformers, often set at different powers. The impedance meter ensures that you don't exceed the power amplifier rating. It's also very handy for checking (usually!) long speaker lines for shorts or open circuits.

With a 1Ω to 10kΩ range, it will cover just about any conceivable application. An impedance meter is also critical for measuring low-impedance loudspeaker crossovers, shorted turns on mains transformers and so on.

All in all, an impedance meter should be part of any technicians arsenal.

The Redback Q2003 is exclusive to Altronics stores and authorised resellers for $260.00 inc GST.

Contact:
Altronics Distributors
(Head Office): 174 Roe St, Perth WA 6000
Tel: 1300 797 007
Web: www.altronics.com.au

Sanyo Denki AC and DC fans & blowers from Digi-Key

Sanyo Denki's ultra-long life, high reliability rugged AC and DC fans and blowers are now available for immediate shipment from Digi-Key Electronics.

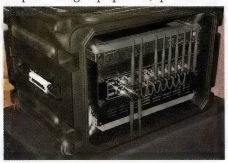
Sanyo Denki produces fans with a high temperature range, long life, and environmental protection options, which dramatically increase the overall application life of many products and designs.

The fans and blowers are ideal for many applications including automation, server cabinets, telecom, medical, the food industry and anywhere air needs to be moved.

Contact:
Digi-Key
Tel: Aust (1800) 285 719 **NZ:** 800 449 837
Web: digikey.com.au digikey.co.nz

An announcement from a Perth (Australia) and Columbia (USA) organisation in January has the drone-world all a-twitter.

department 13 announced a flagship counter-drone product, MESMER. It's a unique, patented product which enables an effective and safe method of protecting equipment, personnel and infrastructure from potentially dangerous drones.



The MESMER platform uses advanced automated detection and mitigation strategies to stop, redirect, land or take control of drones across a range of national security, defence and commercial scenarios.

Highlighted in a January 19 episode of the USA Today Show, MESMER's key differentiator is its ability to manipulate weaknesses in all digital radio protocols and take control of a drone's computer.

Contact:
department 13
(Head Office): 7021 Columbia Gateway Dve, Suite 175, Columbia, MD 21046 USA
email: info@department13.com

SERVICEMAN'S LOG

Fixing a guitar amp is an enjoyable task

Dave Thompson*

Which would you rather do, solve a problem with a laptop PC or fix a large guitar amplifier, and in the process maybe play a few riffs? It was a pretty easy choice and involves work which is almost my hobby.

Items Covered This Month

- Guitar amplifier repair
- Car battery charger
- Westinghouse oven repair

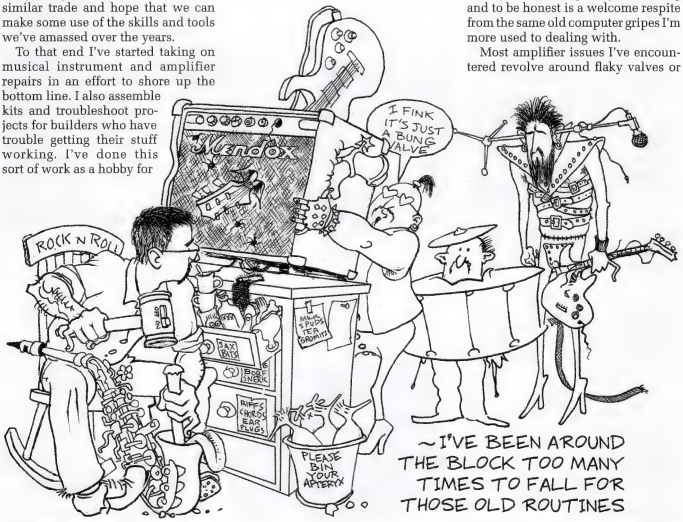
*Dave Thompson runs PC Anytime in Christchurch, NZ.
Website: www.pcanytime.co.nz
Email: dave@pcanytime.co.nz

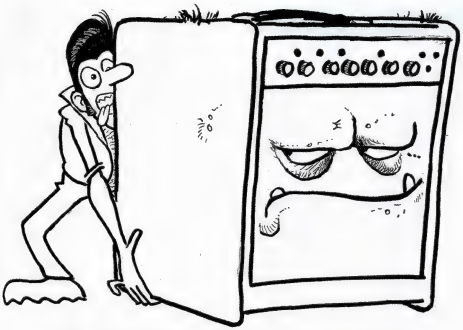
I've said it before and I'll say it again; the computer repair business is a sunset industry. The golden years of computer-repair guys skilfully assigning IRQs and IP addresses are long gone and those of us trying to eke out a living doing computer work really only have two choices: give it away altogether or diversify into a similar trade and hope that we can make some use of the skills and tools we've amassed over the years.

To that end I've started taking on musical instrument and amplifier repairs in an effort to shore up the bottom line. I also assemble kits and troubleshoot projects for builders who have trouble getting their stuff working. I've done this sort of work as a hobby for the last 40-odd years anyway, so my thinking was that I might as well go 'pro' and try to make a living out of it.

When I say musical instrument repairs, I'm not just talking guitars, although as a guitar player, naturally that has been the focus of work I've done previously. However, since I've been advertising as doing this type of work, I've had several different instruments through the workshop, from keyboards to saxophones as well as the usual busted guitars, faulty amplifiers and effects pedals. This variety makes things very interesting and to be honest is a welcome respite from the same old computer gripes I'm more used to dealing with.

Most amplifier issues I've encountered revolve around flaky valves or





AMPLIFIERS ARE HEAVY BEASTS

dodgy input sockets. So tightening up the sockets and replacing the valves is often all that's required to get things humming again. It isn't surprising that input sockets give out; guitar cables typically have 6.5mm mono plugs at either end and these can exert an awful lot of strain on the sockets mounted in the chassis of an amplifier.

They can get especially strained when the guitarist gets carried away and runs out of cable, or tries those fancy moves where the player throws the guitar back and over their shoulder, relying on the strap-locks to hold everything together until the instrument completes the circle and ends up back in the playing position.

YouTube is full of videos where this manoeuvre fails, usually spectacularly, with the guitar either flying off out of shot and landing off-stage somewhere or worse, ending up taking out one of the other musicians on-stage or tangled up in the drums and cymbal stands.

Getting smacked with a flying guitar is not something to be brushed off lightly; it is only luck that none have hit me over the years! This is exactly why I didn't attempt any of those showy tricks as a guitar player.

For one, I didn't fancy two grands' worth of my guitar sailing through the air to the inevitable (and expensive) smash-landing and two, it just looks stupid, whether the player pulls it off or not. If the cable suddenly runs out during these stage shenanigans, it tears at the sockets at both ends and you end up damaging the amplifier and the guitar.

Input sockets (and speaker sockets, many of which are also simple 6.5mm mono sockets) get a hammering even in normal road use, so tightening or replacing these and replacing dead or dying valves are the sort of bread-and-butter jobs that keep guitar and amplifier repair guys going. Occasionally though, there is a problem outside the square and it is these jobs that make the day more interesting.

A few weeks ago, a client brought in a 6-year-old solid-state 100W guitar combo amplifier complaining of two faults; one was very noisy controls and the other was a dodgy reverb effect.

As part of my job booking-in procedures, I powered the amp up while he was there, partly to assess these problems so we both know exactly what I am expected to fix and also to make sure there aren't any other problems the client might have forgotten to mention.

I've been around the block too many times to fall for those old: "well, it was running perfectly when I dropped it off to you" routines. The best way to make sure there are no surprises is to fire it up and take the time to check it properly. I can recall a few instances over the years when I went to run up a machine and the client suddenly remembers there are other, more serious faults. Nice try, but not on my watch.

After making sure the volume controls were all set to minimum before switching the amplifier on, a wise precaution with all solid-state amps that typically power on instantly, I flicked the switch. It was very quiet for a guitar amp, even with the master volume controls wound up half way, but merely touching one of the two channel volume pots caused some very loud and aggressive-sounding static to come from the on-board 12-inch speaker.

This wasn't just some minor crackling; this was the sort of bone-shaking, full-volume amplified noise that you just knew could do some serious damage to the speaker or even the output components.

The control, labelled 'Growl' on this particular amp, also didn't feel right and would likely need to be replaced. The only way we could get it to settle down was to isolate that input channel and use the second input. That would definitely need to be looked at.

While it was running properly I wound in a bit of reverb to test that effect and the resulting sound was, well, just not right. Usually, the built-in spring reverb circuits on guitar amplifiers give reasonable effect depth and sound output quality but this one sounded like there was something physically wrong with the reverb itself, being very muted and with a muddy sounding output.

While some modern amps boast numerous reverb sound types as part of a digital effects chain, older and more traditional methods involve the use of a spring tank, typically mounted in the bottom of the speaker cabinet.

The theory of how it works is relatively simple; a small transducer sits at each end of a 12-inch long (300-mm) spring. These transducers work somewhat like the voice-coil of a speaker, with a wire coil wrapped around a suspended and movable centre core. The body or coil of the transducer is physically fixed to each end of the tank while the spring attaches to the movable inside parts.

When an audio signal is fed into the input transducer, the sound is converted to movement by the transducer and these physical waves travel back and forth, up and down the spring and produce corresponding signals at the other end, the output of the spring,

which are then fed back into the amplifier and mixed with the original signal. Since the signal that travels along the spring is somewhat delayed compared to the original, and it has several reflected components as the sound waves bounce up and down the spring, a realistic room reverberation effect is produced.

Mixing in more of the delayed signal increases the overall depth of the effect and while it sounds quite primitive, the system works very well; good spring reverbs sound remarkably natural and are often preferred over digitally-created reverb effects. Once again, YouTube has some very interesting videos of DIY spring tanks made from speaker voice coils and all manner of springs, including a very large one made from a Slinky!

Editor's note: for a comprehensive description of spring reverberation, have a look at the project article in the January 2000 issue: www.siliconchip.com.au/Issue/2000/January/Spring+Reverberation+Module

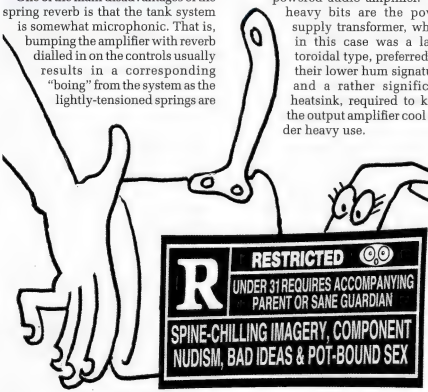
One of the main disadvantages of the spring reverb is that the tank system is somewhat microphonic. That is, bumping the amplifier with reverb dialled in on the controls usually results in a corresponding "boing" from the system as the lightly-tensioned springs are physically moved about in the tank and strike the sides.

This usually isn't an issue, as most instrument amplifiers sit on-stage and don't usually get whacked by anything (except when the guitar player tries that flying guitar trick!). Whatever was causing this amp's reverb issues, I'd have to dig deeper and look into it.

Most instrument amplifiers are heavy beasts, especially the combos (those with built-in speakers) and this one was no different. I'd conveniently forgotten about that side of the job! Oh well, it'd give me a good workout lifting these things up and down from the workbench.

Removal of the amplifier part of it is relatively simple; four long screws hold the metal chassis in and these go down through the top of the cabinet. A portable drill-type screwdriver is a necessity when removing these long screws.

Once removed, the chassis slides out to the front of the cabinet. Inside is what you'd expect from any high-powered audio amplifier. The heavy bits are the power supply transformer, which in this case was a large toroidal type, preferred for their lower hum signature, and a rather significant heatsink, required to keep the output amplifier cool under heavy use.



Being solid-state, there are no large output transformers like you would get in a valve-based amplifier. This is why solid-state amps are often significantly lighter than their valve counterparts.

You may not think it makes much difference but to a jobbing musician, who has to pack his or her own gear up and down of a night, it can make all the difference. Lugging 50 kilos of guitar amp around at 2am, especially after a few cold ones with the bar owners, is not the rock-and-roll ideal. This is why the Rolling Stones need five jumbo jets – to cart all their guitar amps and other gear around!

In this amplifier (back in the real world), a single PCB held all the relevant components. All the potentiometers and input sockets were mounted along the front edge, while the output and switch-pedal sockets were mounted along the back edge. The preamp is typically mounted on this board as well and depending on the amp's size and architecture, this board can also hold the output transistors or modules as well.

In this case however, the output module was mounted on its own small PCB and this was secured to the large aluminium heatsink by a couple of small bolts and copious amounts of heatsink compound, which appeared to have been applied with a trowel.

Why the people assembling these things or the quality-control engineers in the Chinese factory can't take a bit more pride in their work is one of the reasons they are so behind the eight-ball in global engineering standards.

While in this case it is purely cosmetic and doesn't have any effect on the sound or operation of the amplifier, it does make a difference to me. My thoughts on the noisy potentiometer would be that I'd hit it with some contact cleaner and if that didn't clean it up, I'd simply replace it. As the chassis comes out all in one piece, the controls are all still in place and labelled so locating the suspect pot was easy.

It also didn't take much skill to see the cause of the issue. The back cover of the pot had parted company from the front, making it next to useless for controlling anything; more like whimper than Growl! Surprisingly, all the pots were high-end components and not the bargain-basement types I was expecting. Perhaps my assumptions

were a little harsh on this eastern-made amplifier.

I have to say the PCB and internal components were very well-made and professionally wired up, using best-practices to reduce hum and interference. A replacement pot for this would likely cost a few dollars, so as always, I looked for another solution.

I remember back in the day taking pots apart when they got a bit noisy to clean them out; this was before the widespread use of aerosol contact cleaners and besides, my pocket money didn't quite stretch to such luxuries. These pots, like those of yesteryear, were assembled and held together with four clasps that are part of the back cover. When mated with the front half of the pot, these clasps are then folded over to hold the thing together.

This pot looked to have taken a bit of a hit, which had driven the knob and shaft backwards into the back housing and popped a couple of the clasps clear. This is why it made terrible contact, as there was no tension holding the wiper to the carbon track in some places, and too much in others. No wonder it didn't feel right.

I eased the remaining clasps clear and pulled the back free. The shaft had pushed back through, popping a circlip, with only the knob itself stopping the shaft and wiper from coming through further. I pushed back on the shaft and with a bit of pressure, forced it back into position. The circlip clicked into place and the control now moved quite smoothly. I gave all the controls a good squirt of cleaner while cranking them around; easy enough to do when the openings are accessible inside the case.

After sitting the amp on the top of the cabinet and wiring up the speaker and a power cable, I fired it up and touched the pot. Nothing, that is, no noise. I plugged in a guitar and gradually wound it up; the static had once again become a growl. A quick check of the other controls confirmed they were all functioning correctly. That was one issue down; one to go.

With the amplifier chassis out of the cabinet, accessing the spring tank was a lot easier. In this amp, as in many others, the tank is screwed directly to the floor of the cabinet and is enclosed in a leatherette bag, mainly to keep out dust, cigarette butts, roaches, beer and broken glass. This one was held in with two rather long wood-type screws and was easily removed.

Two shielded cables connect it to the rest of the amp via RCA plugs and sockets; one input and one output. The leads protrude through the folded flap of the bag and with the flap open the tank slides straight out.

Once again, it didn't take a brain surgeon to spot the cause of the problem. Half way down the top of the tank was a large dent. When I turned the tank over, I could see the springs were fouling on the dent and this is why the reverb sounded a bit weird.

The bottom of the tank is open, and as I didn't really want to disturb the transducers at either end, I simply held the springs apart either side of the dent with a small piece of plastic cut from an ice-cream container (what would we do without them?). From there it was a simple panel-beating job to flatten the top of the tank and restore sweet reverb once again.

The open back of a combo amp is an inviting repository for power cables, guitar leads, effects pedals and other gig-related detritus. Someone had dropped something a bit too heavy into the space and had impacted into the top of the tank. I advised the owner to be careful of what he carried in there from now on. Rock and roll!

Car battery charger

When switchmode power supplies fail, they can often generate a string of faults. K. G., of One Tree Hill, SA methodically tracked them down in a faulty battery charger that came his way . . .

This repair job involved a 12V, 14A battery charger with a switchmode supply circuit. Designated model CC-1214, it was assembled by Wialki Electronics in Perth, WA and was about the size and shape of a PC power supply.

The internal PCB was branded MeanWell model ESC-240N-R7. This brand is frequently seen on power supplies and their website shows a huge variety of models and types, ranging from open frame units to complete bench supply units.

This particular unit was bought on spec by a friend of mine at a garage sale, the seller advising him at the time that it didn't work. Not much money changed hands and my friend subsequently opened the unit up, hoping that it might be an easy fix. He discovered that the mains fuse had blown but when he replaced it and applied power, the fuse immediately blew again.

That was as far as he was prepared to go with the investigation, probably due to the high voltages which he knew existed in this type of power supply. And so he handed it on to me saying I could have it if it was of any use to me.

I've had quite a bit to do with switchmode power supplies (SMPS), mainly involving modifying cheap PC supplies to deliver a single output of 13.6V at 20A or so for amateur radio transceiver use. And over the years, I've accumulated a few test equipment items which make working on these units easier and safer. These include a variable auto-transformer (or Variac) and an isolation transformer which enables the negative side of the high-voltage DC supply in an SMPS to be grounded.

This is a great help if you want to look at waveforms in that part of the circuit with an oscilloscope, for example. Another useful device is an electronic load. Mine is home-built and will sink 50A or more for short periods.

I also have a plastic box with a 40W incandescent light globe mounted on it, wired so that it can be placed in series with the mains supply. A switch is provided so that the globe can also be shorted out, allowing the full mains supply to be applied directly to the power supply as normal.

With the globe in series with the mains, you can tell immediately if a fault in the power supply is causing a high current to flow. The globe comes on at full brilliance with a dead short. This saves on fuses and possible damage to other components.

Getting back to the charger, my friend had removed both its lid and the screws holding the PCB inside the case (he had thoughtfully put the screws in a zip-lock plastic bag).

With the unit on the workbench, I could see that the quality of construction was of a high standard, with a double-sided PCB and good quality components. This is in contrast to the average PC power supply made to a much lower budget.

I began by checking the fuse and it was indeed blown. I then replaced it and connected the device to the mains via the aforementioned light globe unit. As soon as I applied power, the globe went to full brilliance, confirming the presence of a short circuit.

Westinghouse GGP475WNG gas wall oven

Recently, John W., from Hillarys, WA, was looking forward to freshly baked muffins but the cook reported that there would no muffins unless he could do some repair magic. He managed to conjure up a cure . . .

When I got the call from my daughter about her non-working oven, I thought it would be as simple as turning the power off for 30 seconds to reset the electronics but it was not to be. I then pulled the oven out from the cupboard, rested it on a chair and removed the top cover.

I found a circuit diagram on the top cover that seemed rather simple except for the section marked "ignition module". This was a small PCB with a microprocessor and looked rather complicated for the job it was supposed to do.

The board was labeled Tytronics DSI230 so I investigated on the net to find some basic information but could find no circuit diagram. Using the circuit from the top cover, I proved that the thermostat was working and that it was providing 230VAC to the thermostat pin on the PCB when the oven was turned on.

The other terminals on the PCB went to mains Active, Neutral and the gas solenoid. After removing the PCB I traced out some of the circuit that was connected to the input pins and found that the 230VAC was fed via two separate capacitors, 100nF (C12) and 1.5µF (C1), to a switch-mode power supply which provided 10V DC. A partial circuit is shown in Fig.1.

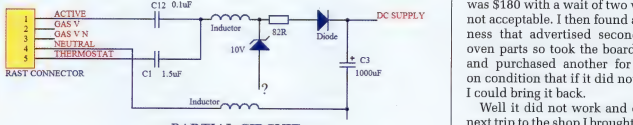


Fig.1: This partial circuit of the supply on the microprocessor PCB shows that the DC supply could be derived from two capacitors, depending on whether the oven was in standby (C12) or operating (C1).

When 230VAC was applied to the oven there was no DC present from the supply but when I bridged across to the thermostat terminal, there was 10V across the 1000µF capacitor and a LED was flashing, possibly indicating an error code.

So should there be 10V when the oven had power applied or did the circuit only require the thermostat input to be live?

I measured the value of capacitors C1 and C12 to find that C12 which was marked 0.1µF was in fact only 9nF. Thinking this must be the problem, I replaced C12 and put the PCB back in the oven. But I still had no gas valve operation or spark to ignite the gas. I decided that the muffins would have to wait and went out for a coffee with the family.

Next morning I rang Westinghouse and found that a replacement board was $180 with a wait of two weeks; not acceptable. I then found a business that advertised secondhand oven parts so took the board there and purchased another for $110, on condition that if it did not work I could bring it back.

Well it did not work and on the next trip to the shop I brought home three boards to see if any of them would work. One did work, so I now had a working oven and returned it to its spot from the middle of the kitchen. I resolved to return the two

I removed the mains plug from the wall socket and waited a minute or so for any capacitors to discharge, though with a short-circuit in evidence not much voltage would have been applied to any capacitors. I then gave the unit a close visual examination.

The first thing I noticed were bulges in the tops of the two low-voltage electrolytic capacitors in the charger's output section.

In each case, the bulge wasn't severe and there was no sign of leaking electrolyte but they were clearly faulty. I removed them and tested their ESR (effective series resistance) using my trusty "Electronics Australia" ESR meter. They each gave an ESR reading of about five times the expected value and so they were replaced.

Then I did another quick test, although I didn't really expect the short circuit fault to have been cured. Sure enough, the globe again lit to full brilliance when the battery charger was powered up.

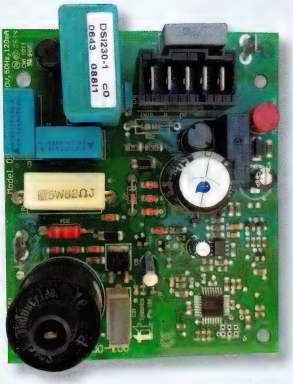
Next on the list of suspects were the two high-voltage switching transistors. They can be tested in-circuit but I like to remove them so that no other parts can confuse the test. It was easy enough to remove them and I then checked them on my semiconductor tester and this indicated a "short circuit" between all three leads on both transistors.

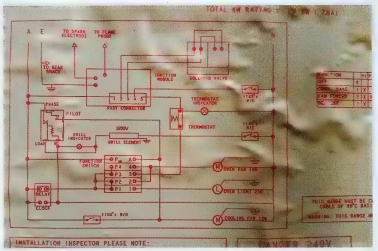
Servicing Stories Wanted

Do you have any good servicing stories that you would like to share in The Serviceman column? If so, why not send those stories in to us?

We pay for all contributions published but please note that your material must be original. Send your contribution by email to: editor@siliconchip.com.au

Please be sure to include your full name and address details.





Above: this part of the circuit diagram located on the top cover of the Westinghouse oven was used for troubleshooting.

Left: this microprocessor board seemed to be more complicated than needed considering its simple functions. Capacitor C12 is the grey block above the 5-way connector while C1 is the large blue block immediately to the left of the connector

non-working boards to the shop the next day but overnight the penny dropped after seeing the oven working as it should.

I realised that when the mains was applied the circuit was activated via C12 and the micro performed some tests on the circuit including, as I found, testing the DC resistance of the gas solenoid. The result of the tests was displayed by the LED flashing on the PCB.

I had an idea that I might have a bit more luck with one of the boards if C12 was a common problem. I rigged up a test circuit with a 220Ω resistor instead of the solenoid and a temporary spark plug.

I then replaced C12 in each PCB. The first one did not work but the second one was a success so I went back to the shop and they gave me my $110 back in exchange for the working board.

I had a chat with the owner and found that he had another seven such boards and he did not know if they were working, so I measured C12 on each one and found them all to be low, under about 30nF. I took them home and tested them with a good capacitor tacked across the faulty one and found that five of seven worked after C12 had been replaced.

The owner of the shop was delighted that he now had six boards that were tested and working and he paid me a nominal sum for replacing five capacitors.

So my oven was repaired for free and I made a bit of pocket money along the way.

It seems that there could be a lot of these units from gas ovens and heaters that are being thrown out simply because a $1.00 capacitor has become faulty.

The transistors were both type 2SC3320 and a search on the net revealed that this device is rated at 400V and 15A, a very conservative current rating for this power level. I didn't have any exact equivalents but I had some with a 400V 9A rating that had been salvaged from a 300W PC power supply. This current rating was still ample and so I decided to give them a try.

I soldered the replacement devices into the board but initially left off the heatsink, as I planned to run the power supply at only a light or with no load until I was sure that it was working. Unfortunately, when I applied power, the lamp again immediately went to full brilliance, so there was still a problem lurking somewhere.

The next thing to test was the bridge rectifier, something I really should have checked before previously applying power. As it turned out, this single package device had a dead short across its AC terminals. I replaced it and checked the resistance between the AC terminals. This was initially low but quickly rose to a higher value as the electros charged, so that was encouraging.

12V was then applied from a bench supply to the mains input terminals. The power supply also passed that test and I felt justified in applying mains power again but still with the light globe in series.

This time, the globe lit only briefly and the charger's DC-powered fan began running. I checked the output voltage and it measured 13.8V, so the unit was back up and running again.

A check again on the net revealed the original transistors were available quite cheaply and so I ordered a pair. My aim was to return the battery charger to its original state with the conservatively-rated devices rather than leave the lower-rated devices I'd substituted to get the unit running.

The replacements duly arrived and were installed, after which I gave the unit a thorough test before putting it away for future use. SC

Part 2 – Getting Started with the Micromite

Last month we introduced the input/output system, making decisions (IF...THEN...ELSE...) and looping (DO...LOOP). One of the outstanding features of the Micromite is its ability to drive a variety of LCD panels, so this month we concentrate on graphics as well as introducing expressions and FOR/NEXT loops.

by Geoff Graham

The standard 28-pin and 44-pin Micromites can drive 2.2, 2.4 or 2.8-inch LCD panels. These are manufactured in enormous quantities for common consumer devices such as air conditioners and coffee makers and as a result they are very cheap. The more powerful version of the Micromite (the Micromite Plus) can drive an even wider range of displays from 1.44 inches to 8 inches (diagonal).

All these displays use TFT (Thin Film Transistor) technology which means that every pixel has an associated switching transistor integrated into the LCD panel. This provides a bright and colourful display which the Micromite can use to show text, lines, circles etc in thousands of different colours. Most of these displays also provide a touchscreen function to make user input simple.

Using these features, even the simplest of projects can sport a colourful display for a wide range of information such as temperatures, voltages and levels.

The best way to experiment with LCDs and the Micromite is to build the Micromite LCD BackPack as mentioned in last month's tutorial and described in the February 2016 issue of SILICON CHIP.

This simple project uses less than ten components and can be built in half an hour. It includes the 3.3V power supply, a 28-pin Micromite and a touch sensitive LCD panel. A kit of these parts is available from the SILICON CHIP Online Shop.

The remainder of this tutorial assumes that you have a running Micromite with a suitable display attached. If you are having trouble getting this set-up working, please refer to last month's article or the February 2016 issue.

The PIXEL command

The 2.2-inch, 2.4-inch and 2.8-inch LCD panels supported by the Micromite have 320 columns and 240 rows of pixels (320 x 240, a total of 76,800 pixels), with each pixel capable of displaying one of 65,536 (2^{16}) different colours. You can control any of these pixels using the PIXEL command. The syntax of this command is:

PIXEL x, y, colour

The first two parameters are the co-ordinates of the pixel that you wish to change and the third is the colour that you want for the pixel.

The coordinates are expressed in pixels with **x** being the horizontal axis and **y** the vertical. The top left of the screen has the coordinate x = 0 and y = 0.

Both the x and y coordinates increase as you move to the right and down the screen and accordingly x = 319 and y = 239 are the coordinates of the bottom-right corner of the screen and the bottom-left is x = 239 and y = 0.

As an example, to make the pixel at the centre of the screen turn yellow, try entering this:

PIXEL 160, 120, 16776960

Don't worry if you cannot see it; each pixel is quite small – so you may need a magnifier!

Now you might be wondering how

the number 16776960 equates to yellow. MMBasic uses a 24-bit number to define a colour (the same as a desktop PC). The top eight bits set the intensity of the red colour, the middle eight bits the green colour and the bottom eight bits the blue colour.

Each 8-bit number can range from zero to 255 (decimal). Zero means that colour sub-pixel is off while 255 means it is fully lit and the other values relate to intensities between these two extremes.

Yellow is produced when the red and green colours are at high intensity and blue is off. Note that colours produced using additive light work differently from paint and ink, which use a subtractive process. For example, with an additive process such as used in an LCD, red and blue combine to make mauve, whereas with red and blue paint or ink mixed together you get brown.

Anyway, if you calculate the 24-bit value with red = 255 and green = 255 using binary arithmetic you will get the number 16776960.

Obviously this is rather clumsy so MMBasic makes it easy for you with the RGB() function. This has the form RGB(red, green, blue) where red is a number between zero and 255 and similar for green and blue. So you could rewrite the command to turn on the pixel with the yellow colour like thus:

```
PIXEL 160, 120, RGB(255, 255, 0)
```

We will cover the details of functions and expressions soon so please bear with us for a short time.

To make it even more convenient for you to specify a colour, the RGB() function allows you to directly name the colour, so you could also turn the pixel yellow using this:

```
PIXEL 160, 120, RGB(yellow)
```

The colours that you can specify this way are red, green, blue, yellow, cyan, purple, white and black (yes, black is considered a colour!)

The 24-bit value used to specify a colour has over 16 million variations but the LCD panel we use can only show 65,536 (16-bit) colours. This need not concern you as MMBasic will automatically choose the closest colour when converting the 24-bit colour for the LCD.

Some of the displays compatible with the Micromite Plus are natively 24-bit so you will get the full range of colours and the driver will automatically re-arrange the RGB value if it differs in format from what the LCD driver IC expects.

Saving Programs

When you save a program to the Micromite (using MMEDIT, XMODEM or whatever) you might wonder where your program has actually been saved to. The answer is that it was automatically programmed into the flash memory of the PIC32 chip.

Yes, the PIC32 includes its own built-in flash programmer! In fact, if you save a very large program, you might see a delay of a second or two which is the time needed by MMBasic to program that large amount of data into the flash memory.

Flash memory is non-volatile which means that it will retain its contents when power is removed. This might not be important for a program that does something simple like the examples in this tutorial but if you have programmed the Micromite to control your garden watering system you will not want it to lose the program during a blackout. The MEMORY command reports on how much memory has been used by the program. With a small program of 20 lines it will display something like this:

```
Flash:
1K ( 1%) Program (20 lines)
59K (99%) Free

RAM:
1K ( 1%) 4 Variables
0K ( 0%) General
49K (99%) Free
```

As you can see, the program used little memory. This is another advantage of the Micromite; the relatively huge memory space means that you can create large and complex programs and still run them on this small and inexpensive chip. If you do manage to exhaust the Micromite's program space or RAM (as we have on occasion), it's time to move to a Micromite Plus which also has the benefit of 2.5 times the execution speed of the regular Micromite. See the Micromite Plus articles in the August-November 2016 issues for more details.

Expressions

We have used the term "expression" before in this tutorial and above we referred to the RGB() function, which is part of an expression.

In programming languages, "expression" has a specific meaning. An expression is similar to a mathematical formula and it can be resolved by the BASIC interpreter to a single number, text string or value. MMBasic evaluates expressions using the same rules that we all learnt at school. For example, multiplication and division are performed first, followed by addition and subtraction.

This means that 2 + 3 * 6 will evaluate to 20, as will 5 * 4 and 10 + 4 * 3 - 2. If you want to force the interpreter to evaluate parts of the expression first, you can surround that part of the expression with parentheses (round brackets), just as in a mathematical formula.

For example, (10 + 4) * (3 – 2) will evaluate to 14 and not 20, as would have been the case if the brackets were omitted. Using brackets does not appreciably slow down the program so you should use them liberally if there is a chance that MMBasic will misinterpret your expression.

As you would expect, you can use variables in an expression in exactly the same way as for straight numbers. You can also use functions in expressions. There are special built-in functions provided by MMBasic, for example, to calculate trigonometric values.

As an example, the following will print the length of the hypotenuse of a right-angled triangle, with variables "a" and "b" holding the lengths of the other two sides. The SQR() function

Photo 1: the result of running a single BOX command. The thickness was set to three pixels, border colour to red and blue colour fill.

returns the square root of a number:

```
PRINT SQR(a * a + b * b)
```

The RGB() function introduced above is another example of a built-in function. MMBasic includes many functions and a lot of them are mathematically orientated. For example:

SIN(r) – the sine of r (in radians)
COS(r) – the cosine of r (in radians)
TAN(r) – the tangent of r (in radians)
ATAN(r) – the arctangent of r (in radians)

There are many more functions available to you and they are all listed in the User Manual.

Note that in the above functions, the value passed to them (**r**) is the angle in radians. In MMBasic you can use the function RAD(d) to convert an angle from degrees to radians (where **d** is the angle in degrees).

This leads to another feature of BASIC which is that you can nest function calls within each other. For example, given the angle in degrees (ie, **d**), the sine of that angle can be found with this expression:

```
SIN(RAD(d))
```

In this case, MMBasic will first take the value of **d** and convert it to radians using the RAD() function. The output of this function then becomes the input to the SIN() function. This is similar to how a mathematical formula works, for example, you may have seen the mathematical expression "f(g(x))", where f(x) and g(x) are any two other functions. This is known in mathematics as "function composition".

FOR...NEXT loops

While we are describing the PIXEL command, it is also a good time to cover FOR…NEXT loops. These are similar to the DO…LOOP construction that we described in the tutorial last month. The difference is that the FOR…NEXT loop will automatically increment a variable through each iteration of the loop and will terminate the loop when that variable exceeds a set value.

This is a surprisingly common requirement in programming. For example, if you want to draw a horizontal line across the top of an LCD you can use the following:

```
FOR x = 0 to 319
  PIXEL x, 0, RGB(yellow)
NEXT x
```

This starts by creating the variable "x" and assigning it the value of 0. MMBasic will then execute the statement(s) within the FOR loop in the usual order (top to bottom) until it comes to the NEXT statement. This tells the BASIC interpreter to increase the value of "x" by one, go back to the previous FOR statement and execute the statements within the loop a second time. This will repeat until the value of "x" exceeds 319 at which time the program will exit the loop and continue with the statements following the NEXT line.

You can nest FOR loops, one inside the other. For example, the following will fill the LCD with the colour red:

```
FOR y = 0 to 239
  FOR x = 0 to 319
    PIXEL x, y, RGB(red)
  NEXT x
NEXT y
```

It starts by creating the variable "y" (the y coordinate) and setting it to zero, then the inner loop will draw a horizontal line. When this horizontal line has finished, its loop will exit and the outer loop will increment "y" by one and repeat the inner loop to draw another horizontal line. This way the entire screen is covered with a series of horizontal lines.

In the above examples, the variable is incremented by one by default, but you can change this by specifying the step size. The following example uses this to draw a series of dots instead of a continuous horizontal line:

```
FOR x = 0 to 319 STEP 4
  PIXEL x, 0, RGB(yellow)
NEXT x
```

For every iteration of the loop, the variable "x" is incremented by four, which results in every fourth pixel being turned on.

As an aside, sometimes you may find it necessary to abort a FOR loop before all of its iterations have completed. The EXIT FOR command can be used to do this. When this command is encountered within a FOR loop the loop will immediately terminate and the program will continue with the very next statement after the associated NEXT statement.

Similarly, the command CONTINUE FOR will cause execution to immediately skip to the associated NEXT statement and the loop will then continue with its next iteration (or will exit, if it was already on the last iteration).

By the way, similar commands CONTINUE DO and EXIT DO operate on DO loops, which was covered last month.

More graphics commands

If you try the above program to fill the LCD screen with a red colour you will notice that it is very slow. This is because the PIXEL command must be called 76,800 times to turn on all the pixels on the display and even though the Micromite is quite fast, it takes some time to execute the

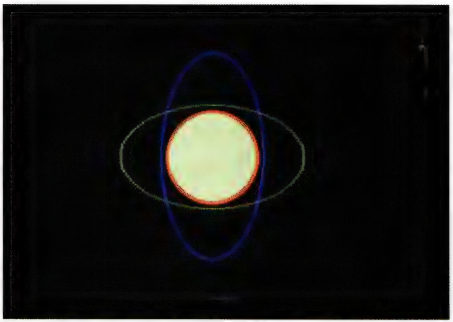


Photo 2: the result of three CIRCLE commands. The centre circle is perfectly round and has a red border that is three pixels thick and is filled with yellow. The other two are ovals with different aspect ratios (0.5 and 1.8) and colours (blue and green).

command this many times and repeatedly transfer the necessary instructions to the LCD panel.

For this reason, MMBasic includes the CLS (**CL**ear **S**creen) command which will fill the screen with a specified colour at a much higher speed. For example, the following will do the same thing as our above program using PIXEL but do it in the blink of an eye:

```
CLS RGB(red)
```

You can specify any colour that you want and if you do not specify a colour the command will fill the screen with the default background colour (which is normally black) and thereby clear the screen.

There are other graphic commands that you can use which are more convenient than drawing pixel by pixel. For example, to draw a line you can use the LINE command which has the form:

```
LINE x1, y1, x2, y2, lw, c
```

x1 and **y1** are the coordinates of the start point of the line and **x2** and **y2** indicate the end point. **lw** is the width of the line (in pixels) and **c** is the colour to use. Using this command you can more easily draw the horizontal yellow line that we did previously like this:

```
LINE 0,0, 319,0, 1, RGB(yellow)
```

One thing to keep in mind is that the lw parameter only applies to horizontal or vertical lines, diagonal lines are always drawn with a line width of one. Another useful command allows you to draw a box. It looks like this:

```
BOX x1, y1, w, h, lw, c, fill
```

x1 and **y1** are the coordinates of the top left corner of the box and **w** is the width (in pixels) while **h** is the height. Similarly to the LINE command, **lw** is the width of the border (in pixels) and **c** is the colour to use when drawing the sides of the box. The parameter **fill** is the colour to use if you want the interior of the box to be filled with a colour.

As an example, the following will draw a box with the boundary drawn in red, three pixels thick and it will be filled with blue (see Photo 1):

```
BOX 20,20, 280,200, 3, RGB(red), RGB(blue)
```

A close relative is the RBOX command which will draw a box with rounded corners. This is particularly useful for drawing touch sensitive buttons on the screen (see the lead photo for an example).

Its syntax is identical to the BOX command except that instead of the **lw** (line width) parameter, it accepts a parameter called **r** (radius) which is the radius of the corners and it defaults to 10 pixels.

The final general purpose graphic command is the CIRCLE command which, as its name suggests, will draw a circle. This looks like this:

```
CIRCLE x, y, r, lw, a, c, fill
```

x and **y** are the coordinates of the centre of the circle and **r** is its radius. **lw** is the width of the line to draw on the circumference circle, **a** is the aspect ratio of the circle, **c** is the colour of the line used to draw the circle and **fill** is the optional colour used to fill the circle.

The aspect ratio is a decimal number which can be a fraction; if it is exactly one, the circle will be perfectly circular; if it is less or more than one, the graphic drawn will be an oval with either the vertical or horizontal axis longer than the other, respectively.

Try the following and you will see how the command works:

```
CLS
CIRCLE 160,120, 45,3, 1, RGB(red), RGB(yellow)
CIRCLE 160,120, 100,1, 0.5, RGB(blue)
CIRCLE 160,120, 50,1, 1.8, RGB(green)
```

In this program, the CLS command first clears the screen then a circle is drawn in red with a border three pixels thick. The circle will also be filled with yellow. Next, a blue oval will be drawn followed by a green oval, each oval drawn with a different aspect ratio. Photo 2 shows the result.

A random example

The following example will draw multiple lines on the screen with random positions and random colours. It is intended to demonstrate many of the techniques that we have covered including variables, expressions, generating colours and the LINE command.

The program uses the built-in RND function, which generates a fresh pseudo-random number every time it is used. Pseudo-random means that the numbers will not come in an obvious sequence but they are not truly random. The output of RND() is a decimal from zero to just below one; it never actually generates the number one but you might get 0.999999.

Normally, the result from RND() is manipulated in some way to give a "random" number in a specific range of values. For example, if you want to

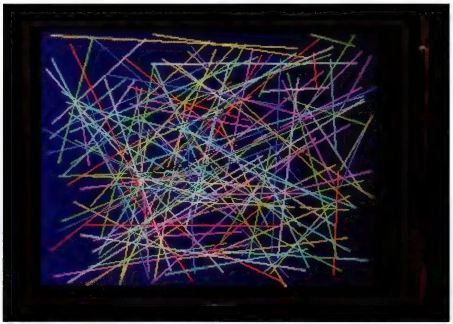


Photo 3: the result of running the random lines example program. The start and end positions of each line is chosen at random (using the RND function), as is the colour used to draw the line. The background is dark blue.

generate a random integer in the range of zero to 319 you would multiply the result of the RND function by 320 and then round it down.

This program is deceptively simple but it will generate a kaleidoscope of different coloured lines that fill the screen with colour:

```
CLS RGB(0,0,128)
FOR nbr = 1 to 150
  x1 = RND * 320
  y1 = RND * 240
  x2 = RND * 320
  y2 = RND * 240
  r = CINT(RND) * 255
  g = CINT(RND) * 255
  b = CINT(RND) * 255
  LINE x1, y1, x2, y2, 1, RGB(r, g, b)
NEXT nbr
```

The program starts by using the CLS command to clear the screen with a dark blue colour and then it enters a loop starting with the FOR command and ending with the NEXT command.

The NBR variable is used to count the number of times that the loop has been executed and after 150 times, the program will end. You can vary the number of lines if you wish but we found that 150 resulted in a nice display.

Within the loop, the program calculates the various required parameters (all of which are effectively random) and then executes the LINE command with these parameters.

Calculating the start and end coordinates is straightforward but generating the random colours requires some explanation. Remember that the RND function generates a random number between zero and slightly less than one.

The CINT() function will round this fractional number either up or down to an integer (a whole number without a fraction). If the number is less than 0.5 it will be rounded down to zero, otherwise it will be rounded up to one.

The result of CINT(RND) will then be either a random zero or one. Multiplying this by 255 will give a number which is either zero or 255. Taking the red colour for example this means that red will be off (number is zero) or full on (number is 255). With all three colours (red, green, blue) being either full off or full on this will generate the eight main colours (red, yellow, cyan, etc) which results in a vivid set of colours. See Photo 3 for an example of the result of running this program.

Program structure

So far we have been using small programs as our examples but before we move onto larger programs we need to cover some details of a BASIC program's structure.

A BASIC program starts at the first line and continues line by line until it runs out of commands to execute or hits an END command, at which point MMBasic will display the command prompt (>) on the console and wait for something to be entered by the user.

A program consists of a number of statements or commands, each of which causes the BASIC interpreter to do something (the words statement and command generally mean the same and are used interchangeably in this tutorial).

Normally, each statement is on its own line but you can have multiple statements in the one line if you wish with each separated by the colon character (:). For example:

```
a = 24.6 : PRINT a
```

Each line can start with a line number. Line numbers were mandatory in the early BASIC interpreters, however, modern implementations (such as MMBasic) do not need them. You can still use them if you wish but they have no benefit and generally just clutter up your programs. This is an example of a program that uses line numbers:

```
50 a = 24.6
60 PRINT a
```

GOTO command

BASIC has a number of constructs that you can use to control the flow of execution in a program. We have covered IF...THEN...ELSE... and loops using DO...LOOP or FOR...NEXT. Another method is the GOTO command. This essentially tells MMBasic to jump to another part of the program and start executing from there. The target of the GOTO can be a line number (as explained above) or a label.

A label is an identifier that marks part of the program. It must be the first thing on the line and it must be terminated with the colon (:) character. The label can be up to 32 characters long and must follow the same rules for a variable's name. For example, in the following, LoopBack is a label:

```
LoopBack: a = a + 1
```

When you use the GOTO command to jump to that particular part of the program, you would use the command like this:

```
GOTO LoopBack
```

To put all this into context, the

following program will print out all the numbers from 1 to 10:

```
z = 0
LoopBack: z = z + 1
PRINT z
IF z < 10 THEN GOTO LoopBack
```

The program starts by setting the variable z to zero then incrementing it to 1 in the next line. The value of z is printed and then tested to see if it is less than 10. If it is less than 10 the program execution will jump back to the label LoopBack where the process will repeat. Eventually the value of z will be 10 and the program will run off the end and terminate.

Of course, you could use a FOR loop to do the same thing and it would be simpler so this example is purely designed to illustrate what the GOTO command can do.

In the past, the GOTO command developed a bad reputation. This is because if it is misused, a programmer can write a program that continuously jumps from one point to another (often referred to as "spaghetti code") and that type of program is almost impossible for another programmer to understand.

With constructs like the multi-line IF statement and DO loops, the need for the GOTO statement has been reduced and it should be used only when there is no other way of changing the program's flow.

In fact, one of the more useful instances where you may need GOTO is for debugging or error handling with the use of a label in a separate part of the program.

Another potential valid use for GOTO is to jump back to the start of a DO or FOR loop without testing the loop condition or incrementing any variables, which is sometimes necessary.

Comments

With all programs it's a good idea to provide comments and notes to help anyone who has to later maintain or modify the program. These should be used to explain any non-obvious parts of your program and generally inform someone who is not familiar with the program and what it is doing (remember that this could easily be you in a few years' time).

Comments are usually the first thing that someone will read when they pick up a program listing and extensive comments are regarded as one of the hallmarks of a good programmer.

Having said that, some programmers believe that it's more important to write readable code than it is to add comments extensively.

In MMBasic, a comment is any text that follows the single quote character ('). Comments can be placed anywhere in a program and when MMBasic sees the comment character it will skip to the end of the line and resume executing your program starting will the following line. The following are some examples:

```
' calculate the hypotenuse
PRINT SQR(a * a + b * b)
```

OR

```
INPUT var ' get the speed
```

That is all for this session. Next month we will cover some more graphics programming including responding to touch on an touchscreen LCD panel, drawing text and buttons, and some advanced features such as data types and arrays. SC

Getting more information on the Micromite

The Micromite is a fully functional computer with a multitude of facilities and the Micromite User Manual which describes it adds up to almost 100 pages. This manual is the ultimate reference for the Micromite and covers everything from the I/O pins through to functions that you might only need in specialised circumstances. It is in PDF format and available for free download from the SILICON CHIP website (at www.siliconchip.com.au/Shop/6/2907) and the author's website (http://geoffg.net/micromite.html).

This tutorial (including the parts to come in future months) will go through many aspects of the BASIC language but it cannot cover everything. For example, many commands have additional features that are only used in special circumstances. So it would be worthwhile downloading the manual and having it handy as you read through the tutorial. That way you can explore the full detail of a command that might interest you.

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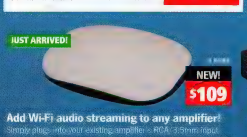

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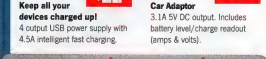

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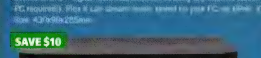

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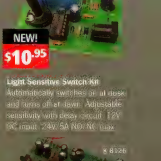

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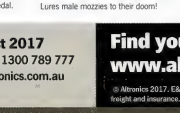

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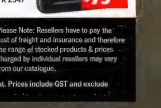

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Build the SC200...

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- a worthy successor to the popular SC480

In this third instalment, we provide the SC200's performance details which demonstrate that it delivers much more power than its predecessor, the SC480; about three times the power, in fact. We also describe the required power supply, the testing and set-up procedure and how to build lower-power versions of the amplifier.

The SC200 is our new workhorse audio amplifier module and while it doesn't have the extremely high performance of our Ultra-LD series, it's still more than comparable with most brand-name hifi amplifiers and it also has power aplenty. It's also easier to build and the parts cost significantly less than the Ultra-LD.

Fig.7 shows where the SC200 has the biggest advantage over the 14-year old SC480 design and that's in power output. The first thing you may notice is that below 10W, the total harmonic distortion of the SC200 is slightly higher than the SC480 but that's simply because it has more gain.

Since both designs use BC557 transistors at the input, their absolute noise figure is very similar but since the SC200 delivers a lot more power, it needs more gain and this also amplifies the noise more.

Hence while the SC200's signal-to-noise ratio relative to full power is 1dB better than the SC480, the noise at a particular power level will be slightly higher.

Having said that, at power levels above 10W the SC200 delivers significantly lower distortion. The SC480 runs into clipping at around 55W for 8-ohm loads and 70W for 4-ohm loads while the SC200 delivers a clean output up to power levels of 135W for 8-ohm loads and 200W for 4-ohm loads.

Music power (ie, for short bursts such as percussion instruments) is even higher, at around 150W into 8 ohms and 250W into 4 ohms. So the SC200 has substantially more power output than the olde SC480.

Fig.8 shows distortion for the new SC200 and old SC480 designs at the same power level, into the same resistive loads and over the entire audible frequency band. We've used the plots for the TO-218 (plastic package transistor) version of the SC480 to be fair, since it is the more modern of the two designs that were originally presented and it gave slightly better performance.

As you can see, the shapes of the distortion curves for both designs are very similar but at the power levels used here, the SC480 has about 1/3 the distortion at all frequencies.

Note though that we have filtered out some of the noise with a 30kHz bandwidth, to allow us to better see the harmonic distortion; the SC480 article doesn't state what bandwidth was used so it's difficult to make an

Part 3 – By NICHOLAS VINEN

"apples-to-apples" comparison.

We have shown the projected high frequency distortion with dotted lines, taking into account the fact that the limited bandwidth will filter out some of the higher harmonics for those frequencies.

Given that noise has less of an effect on the distortion measurements at higher frequencies, because it becomes a less significant proportion of the rising THD+N, this does suggest that the SC200 will have noticeably lower distortion at higher frequencies, at least into 8-ohm loads, and should sound slightly better when driving 4-ohm loads too.

Fig.9 compares the frequency response of both amplifiers at 10W into an 8-ohm load. The frequency response of the SC480 is -1.8dB at 20Hz and -1.6dB at 20kHz. By comparison, the SC200's response is astonishingly flat at just -0.06dB at 10Hz and -0.13dB at 100kHz.

That more extended bass response will certainly be apparent if your CD player and your discs have very low bass signals (such as those from a pipe organ with 64-foot pipes!) and if your loudspeakers have the bass performance to match. At the other end of the spectrum, you will need young ears able to hear up around 20kHz and speakers and a good program source to be able to notice the difference.

Power supply

The power supply for the SC200 is identical to that used in the Ultra-LD Mk.2, Mk.3 and Mk.4. We rectify the output of a 40-0-40V toroidal transformer and feed it to a 6 x 4700µF capacitor bank to generate the nominal ±57V supply rails. The power supply PCB also carries optional circuitry to derive a ±15V preamplifier supply from a second 15-0-15 transformer, or a secondary winding on the main transformer.

The full circuit for the power supply is shown in Fig.10. This shows component values for the full-power rated supply but also for a lower voltage version which will reduce the power output slightly, to 75W into 8-ohm loads and 110W into 4-ohm loads. Note that this is still significantly more than the SC480 could deliver.

There isn't a great deal to the power supply circuit. An external 35A bridge rectifier converts the AC from the transformer into pulsating DC which is used to charge the two large capacitor banks. LED1 and LED2 act as bleeders, to discharge this bank after switch-off and also show when the supply is live.

A separate 1A on-board rectifier comprising diodes D1-D4 and two 2200µF capacitors converts the 15-0-15V AC output of the secondary windings to around ±20V DC which is then fed to a pair of linear regulators to produce the ±15V rails for the preamplifier (or whatever other circuitry you need to power within the chassis).

The power supply PCB overlay is shown in Fig.11. The preamplifier regulator section at right can be cut off if you don't need it, or want to mount it elsewhere. The output

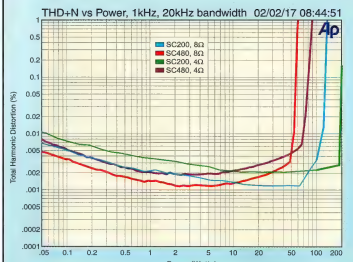


Fig.7: total harmonic distortion from 50mW up to 200W for the new SC200 amplifier, compared to the older SC480 design. Distortion is slightly higher below 10W due to the increased gain and thus noise, but significantly improved for powers above 10W and maximum power is much higher.

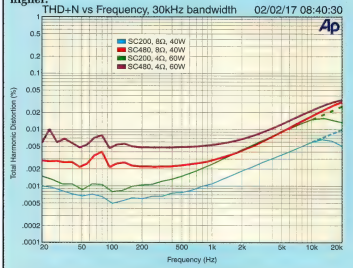


Fig.8: distortion versus frequency at 40W (8-ohm load) and 60W (4-ohm load). These power levels are the nominal output powers for the SC480 and this allows a direct comparison. As you can see, the distortion of the SC200 is lower, especially for 8-ohm loads.

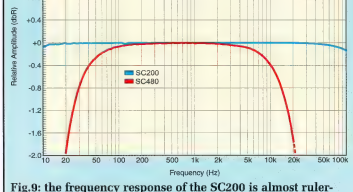


Fig.9: the frequency response of the SC200 is almost ruler-flat over the range of 10Hz-100kHz and should result in greatly extended bass, compared to the SC480.

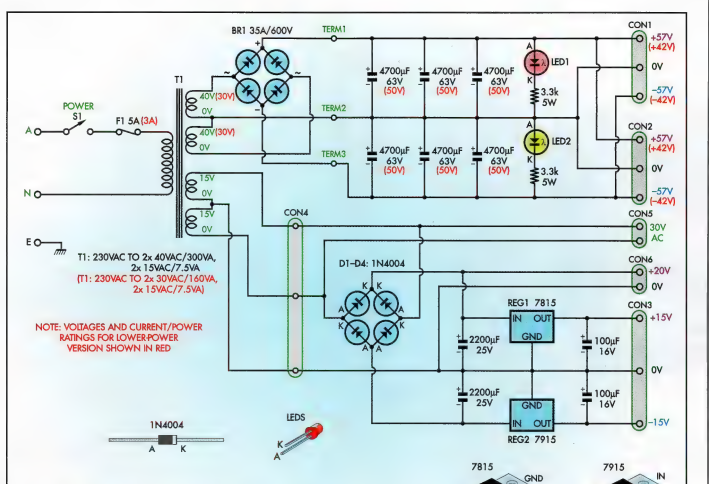


Fig.10: complete power supply circuit for the SC200. This is the same arrangement as used for the Ultra-LD Mk.4. Depending on which transformer is used, the main DC rails are either ±57V, giving 135W into 8Ω and 200W into 4Ω, or ±42V, giving 75W into 8Ω and 115W into 4Ω.

of the bridge rectifier is connected via three spade quick-connect terminals while two sets of DC outputs are provided on either side, making it easier to build a stereo amplifier.

While we show a couple of wire links on this PCB, production boards should have WIDE top layer tracks joining those points, so fitting these wire links is not necessary. Check your board to verify this before starting assembly. The parts list for building the power supply is included later on in this article.

Lower power amplifier module

If you want to build the lower voltage power supply, using a 30-0-30VAC transformer which gives around ±42V DC, you need to make some slight changes to the amplifier modules.

The most important change is that the 22kΩ resistor between the collector of Q7 and ground (to its right on the PCB) must be changed to 15kΩ.

It's also a good idea to change the two 6.8kΩ resistors at the collector of Q6 (one to its left and one below VR2) to 4.7kΩ however this is less critical and it will probably work OK with the original values.

Building the power supply

You'll need to build a power supply before you can test the amplifier module(s). Use the overlay diagram in Fig.11 as a guide to fit the components to the PCB, which is coded 01109111.

Note that the power supply module kit is available from Altronics; Cat K-5168 (note: does not include transformer – you choose which one you want).

Assuming you do want the low voltage outputs, fit the four 1N4004 diodes (D1-D4), orientating them as shown. Then install the two 3-terminal regulators. You will need to bend their leads down by 90° so that they fit the PCB pads with the tab mounting hole lined up correctly. Attach each regulator to the board using an M3 x 6mm machine screws, shakeproof washer and nut, taking care not to get the two different types mixed up. Solder the leads after the screws have been tightened.

The two LEDs can go in next. These sit flush against the PCB with the flat side of the lenses orientated as shown on the overlay.

Follow these with the two 3.3kΩ 5W resistors. These should be stood off the board by about 2mm, to allow the

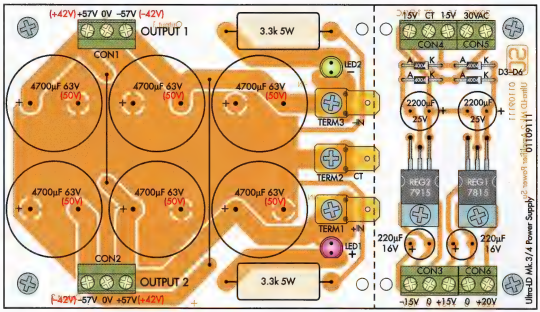


Fig.11: use this overlay diagram to help you build the power supply PCB. You can separate the two halves and even discard the right-hand section entirely if you don't need the ±15V output. The two links shown at left should be incorporated into the top layer of the PCB if you get it from the SILICON CHIP online store.

air to circulate beneath them for cooling (use a cardboard spacer during soldering).

The two 5-way screw-terminal connectors are made by dovetailing 2-way and 3-way blocks together. Be sure to fit these assemblies with the wire entry holes facing towards the adjacent edge of the PCB.

The two 3-way terminal blocks for the ±57V (or ±42V) outputs can then go in. Alternatively, instead of fitting these blocks, you can solder the DC supply leads directly to the PCB pads if it will be mounted right next to the amplifier modules.

The three Quick-Connect (spade) terminals are next on the list. If you are using PCB-mount connectors, simply push the pins through and solder them in place. It will take a while to heat the connectors so that the solder will "take". However, be careful not to overdo it, as the solder could "wick" through the hole and onto the spade section.

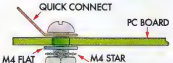
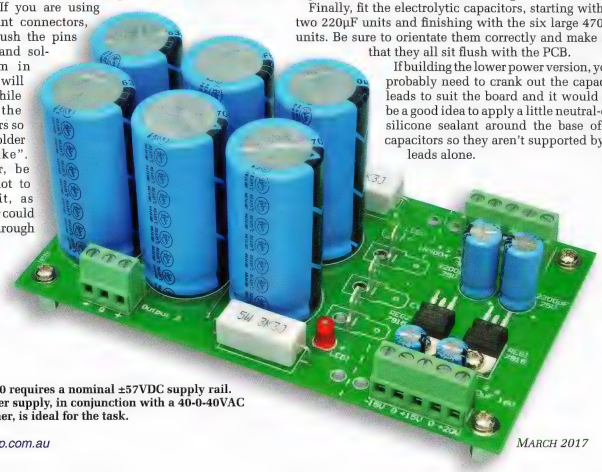


Fig.12: if using the chassis-mount spade terminals on the power supply board, fit them as shown here.

If you are using 45° chassis spade lugs instead, screw them down tightly using M4 machine screws, nuts and washers – see Fig.12. If you can't get single-ended chassis lugs, cut one side off double-sided lugs.

Finally, fit the electrolytic capacitors, starting with the two 220µF units and finishing with the six large 4700µF units. Be sure to orientate them correctly and make sure that they all sit flush with the PCB.

If building the lower power version, you'll probably need to crank out the capacitor leads to suit the board and it would also be a good idea to apply a little neutral-cure silicone sealant around the base of the capacitors so they aren't supported by the leads alone.



The SC200 requires a nominal ±57VDC supply rail. This power supply, in conjunction with a 40-0-40VAC transformer, is ideal for the task.

Parts List – SC200 Power Supply

1 PCB, code 01109111, 141 x 80mm
4 3-way PCB-mount terminal blocks, 5.08mm pitch (CON1-4) (Altronics P2035A or equivalent)
2 2-way PCB-mount terminal blocks, 5.08mm pitch (CON5-6) (Altronics P2034A or equivalent)
3 PCB-mount or chassis-mount spade connectors (Altronics H2094)
3 M4 x 10mm machine screws, nuts, flat washers and shake-proof washers (if using chassis-mount spade connectors)
4 M3 x 9mm tapped Nylon spacers
10 M3 x 6mm machine screws
2 M3 shake-proof washers and nuts

Semiconductors

1 7815 regulator (REG1)
1 7915 regulator (REG2)
4 1N4004 1A diodes (D1-D4)
1 5mm green LED (LED1)
1 5mm yellow LED (LED2)

Capacitors

6 4700µF 63V [50V*] electrolytic
2 2200µF 25V electrolytic
2 220µF 16V electrolytic

Resistors

2 3.3kΩ 5W

Additional parts

1 300VA 40-0-40V + 15-0-15V transformer OR
1 160VA 30-0-30V + 15-0-15V transformer*
1 35A 400V chassis-mount bridge rectifier
1 chassis-mount IEC mains input socket with fuseholder and fuse
Various lengths mains-rated heavy duty hookup wire
Various spade crimp connectors
Cable ties, heatshrink tubing, etc. * for lower power version

Cabling

Note that it's important to use the thickest wire you can easily fit into the terminal blocks and to keep the wiring as short and as tight as possible.

Each set of three wires from the power supply to the amplifier module should be tightly coupled, eg, by twisting them together and/or covering the bundle with a length of heatshrink tubing – ideally both.

Otherwise, the Class B currents flowing through the supply leads could couple into the amplifier module(s) and ruin the performance.

Be very careful when inserting the wires into the 3-way terminal block that you get the polarity right. Refer to the wiring diagram, Fig.13, and ensure your wiring polarity matches this. The 4-way pluggable connector for CON2 is used to run a pair of heavy wires to the speaker terminal (which should ideally be twisted together) from the terminals labelled Out and GND and optionally, two more to a headphone socket, labelled HP and GND.

Initial testing

If you're confident you've built the amplifier module correctly, it is possible to simply wire it to the power supply and fire it up. But we suggest a more prudent approach, so it's much safer to first wire 68Ω safety resistors in series with the supply connections as this will reduce the chance of damage if something has gone wrong.

The easiest way to do this is to insert one lead of a 68Ω 5W resistor into each of the two terminals at either end of the block and do the screws up tightly, then similarly screw the other ends into a 3-way mains terminal block. You can use insulated wire or a 0.1Ω 5W resistor for the ground connection. This arrangement is shown in Fig.14.

The advantage of doing it this way is that you can easily monitor the current flowing through the resistors with a DMM (in volts mode) and the leads are unlikely to short together, as long as they are carefully arranged initially.

The other side of the terminal block is wired to the DC outputs of the power supply. This will need to be built and wired up inside an earthed case. The simplest solution is to build the power supply into the case, as you intend to use for your final amplifier, and simply run an extra-long 3-way lead out of the case for testing purposes.

Don't skimp on this arrangement; make sure all the mains wiring is properly insulated and anchored for the tests. Once you have verified the module(s) are working you can then mount them in the case and complete the amplifier. Refer to the notes on putting the power supply together later in this article (under the "Chassis Assembly" heading).

Before you plug the power supply connector into CON3 on the amplifier board, switch on the now complete power supply and verify that the voltages at its output terminal are correct.

The exact DC voltages will vary depending on your mains supply but for the full power version, you should get something like 54-57V or 39-42V for the low-power version. Be especially careful to check for the correct polarity.

Switch off and wait for the LEDs on the power supply board to go out before connecting the module. Then connect a DMM set to measure volts across each safety resistor using alligator clip leads. If you don't have two DMMs, monitor one resistor. If you don't have alligator clip leads, you will have to hold the probes in place after switching power on.

Wind VR1 fully anti-clockwise and set VR2 to its halfway position using a small jeweller's screwdriver. Ensure F1 and F2 have not been fitted, then switch power on and check the onboard LEDs and the DMM readings. You should see LED1 (blue) light up along with LEDs2&4 (red). LED6 may flicker initially but should not stay on. Check for a reading of just under 1V across each of the safety resistors and verify that the two readings are close in value.

Assuming it's OK, switch off and wait for the LEDs to go out, which will probably take a couple of minutes. Then fit F1 and F2, then switch back on and re-check everything. This time LED3 and LED5 (green) should light up but not much else should have changed.

Soldering a 5W resistor across a blown fuse makes for a handy way to limit current through the amplifier's output stage during testing and adjustment.

If it does then the output stage is suspect, eg, it could be an isolation failure on one of the output transistor insulating washers.

You can now check the output offset voltage, measuring between Out and GND on CON2. It should be less than 25mV and is usually about 10mV. Be careful not to short the two pins together!

Now rotate VR1's screw clockwise slowly while monitoring the voltage across a safety resistor. At first nothing should happen but eventually it will rise. This indicates that the Vbe multiplier is working; stop turning VR1.

Rotate VR2 and check that the offset voltage changes. You can trim it close to 0mV now, although you will need to make the final adjustment later.

If you have a scope and signal generator, you can feed a low-level signal into the amplifier (<250mV RMS) and check that the output signal looks clean. Note that with the safety resistors in-circuit, it won't drive a load, nor will it handle high-swing or high-frequency signals.

Quiescent current adjustment

Switch off, wait for the LEDs to go off and remove the safety resistors. These can now be soldered across a pair of blown fuses to make handy resistor fuse adaptors; see the adjacent photo . Fit these in place of F1 & F2 and wire up the power supply direct this time, as shown in Fig.13.

Given that the earlier tests were successful, it's unlikely anything will go wrong at this stage but it's still a good idea to have the safety resistors in place of the fuses initially. These limit the current through the output stage to about 840mA if there is a fault. Note that the 68Ω resistors will quickly burn out under such circumstances (since they would be dissipating over 40W).

Now use the following procedure to set the quiescent current and trim out the offset voltage.

STEP 1: check that the safety resistors are installed and that their leads can't short to any adjacent parts (note: do NOT connect the loudspeaker to the amplifier during this procedure).

STEP 2: connect a DMM set to volts across one of the safety resistors (alligator clip leads are extremely handy in this situation).

STEP 3: turn trimpot VR1 fully anti-clockwise. This can take as many as 25 turns but it will continue to turn even so. Many (but not all) multi-turn trimpots click when they are at the end-stop. If in doubt, check the resistance across

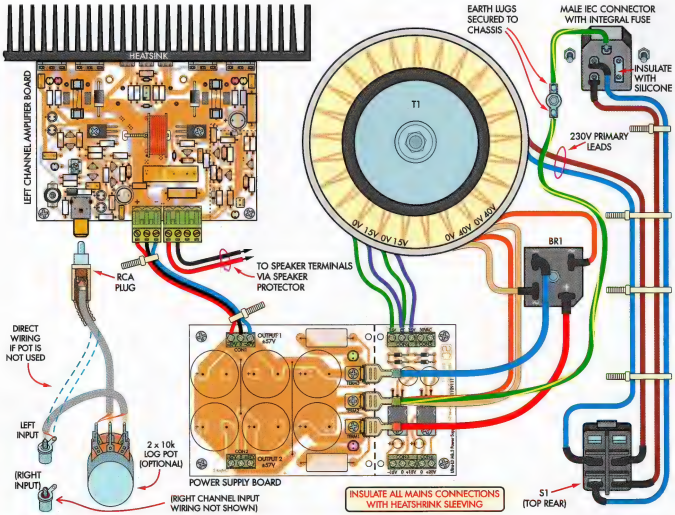


Fig.13: this shows how to wire up the amplifier module, power supply, volume control and signal input. This should give you a working mono amplifier. You can connect a second amplifier board to the same power supply, in a similar fashion as shown here, to build a stereo amplifier. Don't forget the speaker protector!

it – it should be about 1kΩ.

STEP 4: check that the power supply is off and that the filter capacitors are discharged (LEDs off!), then connect the ±57V supply to the module. Check that the supply polarity is correct, otherwise the amplifier will be damaged when power is applied.

STEP 5: apply power and check the voltage across the 68Ω resistor. It should be less than 1V (it may jump around a bit). If the reading is over 10V, switch off immediately and check for faults.

STEP 6: using an insulated adjustment tool or a small flat-bladed screwdriver, slowly adjust the trimpot clockwise. Be careful not to short any adjacent components.

STEP 7: after a few turns, the resistor voltage should stabilise and start to rise. Continue until it reads around 6V. It may drift a little but should be quite steady.

STEP 8: switch off, wait for the capacitors to fully discharge (LEDS off) and replace the safety resistors with 6.5A fuses.

STEP 9: connect a DMM set to volts between TP5 (to the upper left of D3) and TP7 (lower right of D3). If you have fitted PC stakes you can use alligator clip leads, otherwise you may need to get someone else to hold the probes in place while you perform the following steps.

STEP 10: reapply power and check that the DMM reads close to 4.4mV. If necessary, readjust trimpot VR1 to bring the voltage close to this figure.

STEP 11: now check the voltage between TP3 and TP7. The reading should be similar. Do the same check with TP4/TP7 and TP6/TP7. This verifies that all the output transistors are working and sharing the load current more or less equally.

STEP 12: adjust VR2 until the voltage across the output pins is less than 0.5mV. This is easier to do if you screw a couple of bits of wire into the top two connections of the pluggable terminal block for CON2 and clip a DMM across it using alligator clip leads. Be extra careful not to short the output terminals together! Note that this is a trial-and-error process because you will probably find each time you remove the screwdriver from VR2, it will take several seconds for the output voltage to stabilise. You will need to make very small adjustments towards the end of the process.

It's a good idea to recheck the quiescent current (ie, between TP5 and TP7) after the amplifier has been idling for a few minutes with the lid on. If the reading is more than 5mV, readjust VR1 anti-clockwise to bring it back below this figure. The stability is such that it should stay below this figure but it's a good idea to check.

That completes the adjustments. Note, however, that if you wish to repeat the above procedure (ie, with the 68Ω resistors in place), you will first have to reset VR1 to minimum (ie, fully anti-clockwise). If you don't do this, the amplifier may latch up when power is reapplied and could burn out the safety resistors.

Troubleshooting

If there's a fault in the module, a likely symptom is either excessive voltage across the safety resistors or the amplifier output voltage is pegged near one of the ±57V supply rails.

If this happens, switch off and wait for the power supply capacitors to discharge. Then check that all the large transistors are properly isolated from the heatsink. You should also carefully inspect all the solder joints on the underside of the board, to make sure that they all have good, shiny fillets and also check to make sure that all the correct component types and values are in the intended locations and none of the polarised components have been installed backwards.

If you still can't find the fault, you will need to power the amplifier up without fuses or safety resistors fitted. Then check the various voltages shown in the circuit diagram, Fig.1 on pages 30 and 31 of the January issue, with reference to the overlay diagrams of Fig.4 on page 80 in the February issue. If you find a voltage which is clearly wrong, this may give you a clue to where the fault lies.

Chassis assembly

If you want to build a complete stereo SC200 amplifier, we suggest you read part three of the article on the Ultra-LD Mk.4 amplifier module, on pages 32 to 44 of the October 2015 issue.

Even better, refer back to our article on building a complete Ultra-LD Mk.3 amplifier in the March, April and May 2012 issues. The procedure to build an amplifier with SC200 modules is virtually identical. You simply substitute the SC200 amplifier modules, which are a similar size and have similar power and signal/input output connector arrangements.

Regardless of how you go about building the amplifier, as mentioned last month, it's vital to include a loudspeaker protection module. For a suitable module, see our designs in the October 2011 (primarily through-hole components) and November 2015 (primarily SMDs) issues.

Volume control

Once you've built the power supply, amplifier module(s) and speaker protector and wired them up, if you are not fitting a full preamplifier in the case, you will probably want to fit a volume control. This is quite simple and Fig.13 shows how to do it using a 10kΩ dual-gang logarithmic law potentiometer.

Basically, you just need to connect the incoming signal wire to the clockwise end of the potentiometer with its shield ground to the anti-clockwise end. The reduced amplitude signals then appear at the wipers and these are connected to the signal wire for the cables going to the amplifier modules, with the shield grounds soldered together with the shields from the incoming wire (ie, to the anti-clockwise end of the potentiometer track). SC

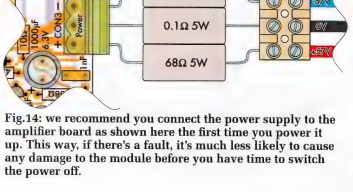


Fig.14: we recommend you connect the power supply to the amplifier board as shown here the first time you power it up. This way, if there's a fault, it's much less likely to cause any damage to the module before you have time to switch the power off.

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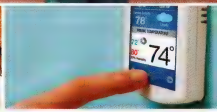

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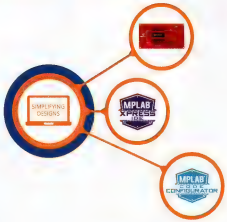

Contact Information
Microchip Technology Australia
Email: aust_nz.inquiry@microchip.com
Phone: +61 (2) 9868-6733

www.microchip.com/simplifying16bit

microchip DIRECT
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Using Cheap Asian Electronic Modules Part 5

The "New Blue" 16x2 LCD module with piggy-back I²C serial interface

by JIM ROWE

This module combines a 16x2 backlit alphanumeric LCD module with a small "piggy-back" module that provides it with an I²C serial interface. This allows it to be hooked up to any of the common micros via only two wires, letting multiple displays (or other I²C devices) share the same 2-wire bus, while also freeing up some of the micro's I/O pins for other purposes.

LCD modules with two lines of 16 characters have been around for many years and we've used them in numerous projects. They are also now much cheaper due to being popular for use with Arduino, Micromite and the Raspberry Pi.

However, many of these Arduino and other micros are a little limited when it comes to I/O pins, which means that the six or seven pins required to interface to a standard LCD module can leave you with too few pins to interface with other components.

This problem can be solved by using an LCD with a serial interface or alternatively, attaching a small piggy-back module to a parallel LCD to provide serial/parallel translation.

By using a piggy-back module that communicates using the 2-wire I²C

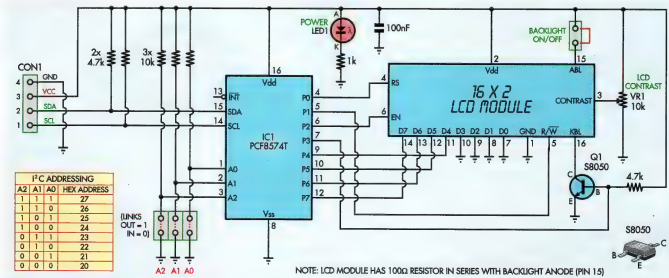


Fig.1: complete circuit for the piggy-back and LCD module together. Some of these modules use a slightly different chip for IC1, that being the PCF8574AT, the main difference being the hex address range is instead between 38h and 3Fh.

protocol, you end up with an LCD that can be driven using just two wires: one for the serial data (SDA) and the other for the serial clock (SCK). That's apart from the ground and power wires (typically +5V).

What's inside

The circuit of Fig.1 shows the LCD module at upper right, with the rest of the circuitry being that of the piggy-back, which connects to the module via the usual 16-pin SIL connector along the top.

All of the serial-to-parallel conversion is performed by IC1, a Philips/NXP PCF8574T device. This is designated as a "remote 8-bit I/O expander for the I²C bus". In other words, it accepts serial data over the I²C two-wire bus, via pins 14 and 15, and it makes the data available in parallel format at pins 4-7 and 9-12.

In this case, output pin 4 is used to control the LCD's RS (register select) control pin, while pin 6 controls the EN (enable) pin and pins 9-12 feed the character codes to pins D4-D7 of the LCD. That leaves pin 5 of IC1 to control the LCD's R/$\overline{W}$ pin, and pin 7 to control the LCD backlight via transistor Q1.

What about pins 1, 2 and 3 of IC1? They're used to set the address of IC1 on the I²C bus. All three pins have 10kΩ pullup resistors connecting them to logic high (V_{CC}) but the LCD module PCB also provides three pairs of tiny pads so that any of the pins can be tied to ground.

This allows the chip's I²C address to be set to any hexadecimal value between 0x20 (32) and 0x27 (39), just by bridging the pairs of pads, as shown in the small table at lower left in Fig.1.

So the default I²C address of the piggy-back module (and thus LCD) is 0x27 with all links out but this can be changed to 0x20 simply by fitting all three links, or to any address in between by fitting one or two links. This allows a number of the LCD-piggyback combinations to be connected to the same I²C bus, with each one given a different I²C address so that the micro driving the bus can send data to any one it chooses.

Other I²C devices can reside on the same bus (eg, temperature sensors, memories, other microcontrollers), as long as you ensure that no two devices have the same address.

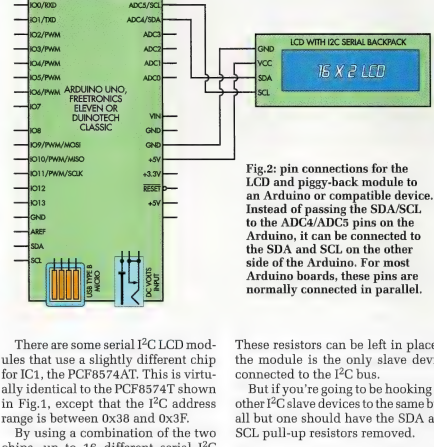


Fig.2: pin connections for the LCD and piggy-back module to an Arduino or compatible device. Instead of passing the SDA/SCL to the ADC4/ADC5 pins on the Arduino, it can be connected to the SDA and SCL on the other side of the Arduino. For most Arduino boards, these pins are normally connected in parallel.

There are some serial I²C LCD modules that use a slightly different chip for IC1, the PCF8574AT. This is virtually identical to the PCF8574T shown in Fig.1, except that the I²C address range is between 0x38 and 0x3F.

By using a combination of the two chips, up to 16 different serial I²C LCDs to be connected to the same I²C bus, provided you use eight with the PCF8574T bridge chip and eight with the PCF8574AT chip.

Fig.1 also shows that the piggy-back has a power-on indicator (LED1), a 2-pin SIL connector and jumper shunt which can be used to disable the LCD's backlight if not required. Trimpot VR1 which can be used to adjust LCD contrast in the usual way (via pin 3).

Note that the SDA and SCL lines connecting between pins 1 and 2 of CON1 and pins 14 and 15 of IC1 are each fitted with a 4.7kΩ pull-up resistor, as the I²C bus uses active-low logic. These resistors can be left in place if the module is the only slave device connected to the I²C bus.

But if you're going to be hooking up other I²C slave devices to the same bus, all but one should have the SDA and SCL pull-up resistors removed.

Using it

This type of module really needs to be hooked up to a micro, and that turns out to be fairly easy to do with any of the popular micros.

All you have to do is connect the V_{CC} and ground pins to a suitable voltage source (which may be the same one that's powering the micro) and the SDA and SCL pins to the I²C bus pins on the microcontroller. Fig.2 shows how this is done with an Arduino Uno or a compatible like the Freetronics Eleven or Duinotech Classic. It couldn't be much simpler.

By the way, although the SDA

Reading Hexadecimal Numbers

In this article values prefixed with "0x" correspond to a hexadecimal number; you might also see values suffixed or prefixed with "h". Reading from left-to-right each character corresponds to a 4-bit long value. With 0-9 being equal to themselves and A-F (case-insensitive) are equal to 10-15 respectively. A hexadecimal value is calculated as if each character is appended to the other to form one long string of bits.

Ergo, 0x5A (or 5Ah) is equivalent to 01011010 in binary and 90 in decimal form. A string of bits can be read as the sum of each individual non-zero bit, with each bit being equal to 2^{n-1} while n is the index of that bit starting from the right. So 0101 is equal to $2^{3-1} + 2^{1-1} = 4 + 1 = 5$. A longer example BC-DEh would just equal to 48350 in decimal and 1011110011011110 in binary.

The underside of the LCD module's PCB has the piggy-back module (black) located above it. The jumper shunt located on the piggy-back module can be used to disable the LCD backlighting if it's not needed.

and SCL pins of the LCD module are shown in Fig.2 connected to the ADC4/SDA and ADC5/SCL pins at upper right on the Arduino, they could instead be connected to the pins marked SDA and SCL on the other side of the Arduino down near the USB connector. On most Arduino boards, these pin pairs are connected in parallel.

It's just as easy to connect the serial I²C LCD module to a Micromite, as you can see from Fig.3.

Of course, connecting the module up to a micro is only half the story. Then you have to work out how to get the micro to send it the data you want displayed.

The complicating factor here is that quite a few people have written "libraries" to make it easier to drive this kind of serial I²C LCD module from an Arduino sketch, by providing a set of simple function calls like:

```
lcd.print("Text");
```

And so on, which is all very well, but even though most of these library files have the name "LiquidCrystal_I2C.h", they are often different in terms of their finer details and compatibility with any particular serial I²C LCD module.

Rather than you going through the same sort of hassles we did to find a suitable library, we'll simply point you at some that we found to work. These are available at the following links:

https://github.com/fdebrabander/Arduino-LiquidCrystal-I2C-library

https://github.com/marcoschwartz/LiquidCrystal_I2C

It's possible that these are actually the same library, because in one place we found the author listed as Frank de Brabander but the maintainer as Marco Schwartz. We found both through the following website: www.arduinolibraries.info/libraries/

Anyway, these libraries do seem to work with the module shown, as you'll find out by downloading the "Hello World" sketch (HelloWorld.ino) from the SILICON CHIP website (www.siliconchip.com.au) and running it. We've included a copy of the library (as a ZIP file) within the package. The resulting display is shown in the adjacent photo.

Incidentally don't forget to change the I²C address shown in the sketch (0x27) to 0x3F (= 3Fh), if your piggy-back module is fitted with a PCF8574AT instead of a PCF8574T.

You'll also have to change this address if you have changed the address using the three small pairs of pads.

How about a Micromite?

Programming a Micromite to talk to the I²C LCD module is not quite as easy as with an Arduino, as currently the inbuilt MMBasic LCD commands only support the parallel interface. You will find a program called I2CLCD.bas in the MMBasic Library, which can be downloaded in zipped-up form from the bottom of this page: http://geoffg.net/maximite.html#Downloads

However, this program was written for a piggy-back module with a different configuration than the one which most piggy-backs seem to use (and we have shown in Fig.1). Then there's a further issue in that the I²C command syntax has changed as MMBasic has evolved. As a result, we ended up having to re-write the software completely.

Changing over the program's commands to suit the different connections between the PCF8574T bridge chip

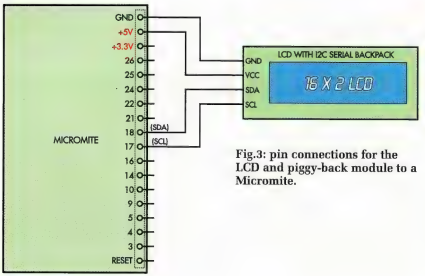


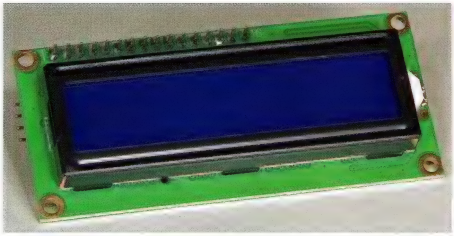
Fig.3: pin connections for the LCD and piggy-back module to a Micromite.

Where To Buy

We've stocked some of these modules in our Online Shop so that you can acquire and experiment with them.

Alternatively, you can find similar units (either pre-assembled or as two separate items) on eBay and AliExpress, and also 20x4 character I²C LCDs which cost very little more than the 16x2 types.

The piggy-back should also work with 20x2 and 16x4 size alphanumeric LCDs, however, these are far less popular than the other two sizes.



The top of the LCD module. The screen is mounted on a PCB measuring 80 x 36mm, while the visible area of the LCD measures 64 x 14.5mm.

and the LCD module itself wasn't too hard. The major difficulty was in getting the program to initialise the LCD's controller correctly.

The correct set-up commands have to be sent to it soon after power is applied, and these commands have to be sent in a particular order, with pauses between them to allow the controller to process them before the next command arrives for correct operation.

After downloading as much information as we could find regarding the correct initialisation sequence and timing for the Hitachi HD44780U and Samsung KS0066U LCD controller chips (which seem to be the two most commonly used in current alphanumeric LCD modules), we were finally able to get the program working correctly and reliably. We found this website most helpful: http://web.alfredstate.edu/weimandn/lcd/lcd_initialization/

Basically, our program (called JRI-2CLCD.bas) just displays a "Hello, world!" message over and over on the LCD; just like the one for the Arduino. You can download this from our website, open it in MMEdit and then upload it to your Micromite and you should get the same display as shown in the photos.

As with the Arduino sketch, you may need to change the I^2C address given for your display's piggy-back, if it has some of the address links fitted or is using the PCF8574AT chip instead of the PCF8574T. Look for this line near the start:

```
DIM AS INTEGER I2CAddr = &H27
' (A2=A1=A0=1)
```

All you need to do is change '&H27' into the correct address for your module. This program provides a good starting point for writing your own MMBasic programs using an I^2C LCD. It's fairly well commented, so you should be able to see how to adapt the program to display other things. SC

Serial USB-UART bridge module – another version

Since writing the third article in this series (for the January 2017 issue), we've become aware of another popular version of the serial USB-UART bridge module based on the CP2102 device. This one is very similar to the one we discussed in the January 2017 article, but differs in two respects. One is that instead of a micro-USB socket on the USB end of the module, it is fitted with a full size type A USB plug – providing a more rugged connection and compatibility with a standard USB type A to type A extension cable.

The other difference (wait for it!) is that the connections to the six pins of the SIL connector on the other end of the module are **NOT** the same as those on the smaller module. So make sure that you allow for the differing SIL pin connections when you connect the module to your micro or other device.

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

ATmega-based Metal Detector with stepped frequency indication

A typical metal detector produces a continuous tone and the operator listens for a slight change in the pitch; whether the tone goes up or down depends on whether the metal near the detector loop is ferrous (ie, has magnetic properties like iron) or non-ferrous.

It isn't always easy to detect the subtle shift in pitch caused by small objects, though. This project addresses that issue.

Rather than the operator acting as a human frequency meter, this one employs an ATmega microcontroller to monitor the oscillator frequency and then produces one of fifteen tones to indicate the size/depth of the buried item.

It simultaneously displays a reading on its LCD which helps the user gauge the magnetic field strength, giving an indication of the type and size of the buried object. The LCD also shows the battery status.

This detector is most suitable for detecting small items like coins within the search area, which is the ~20mm overlapping area of two coils in the search head. However, it is capable of detecting large objects at a distance of over 700mm in air.

This induction-balance metal detector is built around a TL074 quad op amp (IC2) and one gate of a 4066B quad bilateral analog switch (IC3). IC5, a TL071 op amp, provides a virtual ground at half supply, using a resistive divider which is bypassed with a 100nF capacitor.

The search head consists of a pair of identical overlapping coils which effectively form an air-cored transformer. Nearby metal objects interact with its magnetic field, affecting the properties of this transformer and it is these changes which are detected by the circuit.

Op amp IC2a drives one side of coil L1 while its other side feeds back to the inverting input pin 2. The frequency of the resulting sinusoidal oscillation is set to around 10kHz by L1's inductance and the two associated 220nF capacitors. The signal radiated from L1 is coupled to L2 and fed to non-inverting input pin 5 of IC2b which acts as a high-gain non-inverting amplifier (with 48 times gain). IC2b's output is fed to pin 1 of analog switch IC3a.

IC3a gates the signal from IC2b to IC2c when the oscillator signal from IC2a is high. The chopped signal present at pin 2 of IC3a is then amplified by IC2c with a further gain of 47 times, but this time it is set up as an inverting amplifier.

With this configuration, its input pin 9 is held at the same voltage as its output pin 8 whenever analog gate IC3 is off, which causes its output to tend towards virtual ground (ie, half supply).

The amplified signal is fed to a charge pump detector based on signal diodes D1 and D2, producing a DC voltage at pin 12 of IC2d. This is then amplified again, by a factor of two, and fed to trimpot VR1 which is connected as a variable resistor.

VR1, in combination with the 1kΩ fixed resistor and a 10µF capacitor, forms a low-pass filter and the resulting signal is fed to analog input ADC5 (pin 28) of microcontroller IC1.

The micro converts this analog DC signal into a number displayed at the left side of the first line on its LCD, as a voltage in the range of 0-5V.

The micro also uses this DC voltage to control its PWM output at PB1 (pin 15) which is fed to an RC low-pass filter (1kΩ/10µF) and thence to a 4046 voltage-controlled oscillator (VCO). Depending on the voltage at its pin 9 (and therefore the PWM duty cycle), it produces a tone which is then fed to the piezo sounder, to be heard by the operator.

The tone frequency is 10Hz (ie, inaudible) when nothing has been detected. If the search head detects an object (eg, a coin), the audio frequency rises to 500Hz. It rises in steps of 150Hz, up to 2.5kHz, as the voltage from the metal detection circuitry increases. Thus the VCO generates distinct sounds with a variety of frequencies for objects producing weaker or stronger magnetic fields or buried at different depths.

Sensing coils L1 and L2 are identical and wound as follows. Each coil consists of 100 turns of 0.315mm diameter (30 SWG) enamelled copper wire wound on a 100mm diameter former (eg, a piece of plastic conduit).

Remove the completed coil from the former and wrap it with insulating tape. Then fabricate a Faraday shield for the coil by wrapping narrow strips of aluminium foil around it. Make sure that the shield has a 10mm gap at one point. A short length of wire should be connected to the shield which is then covered with insulating tape.

Once both coils have been made, cut a 250mm diameter circle from

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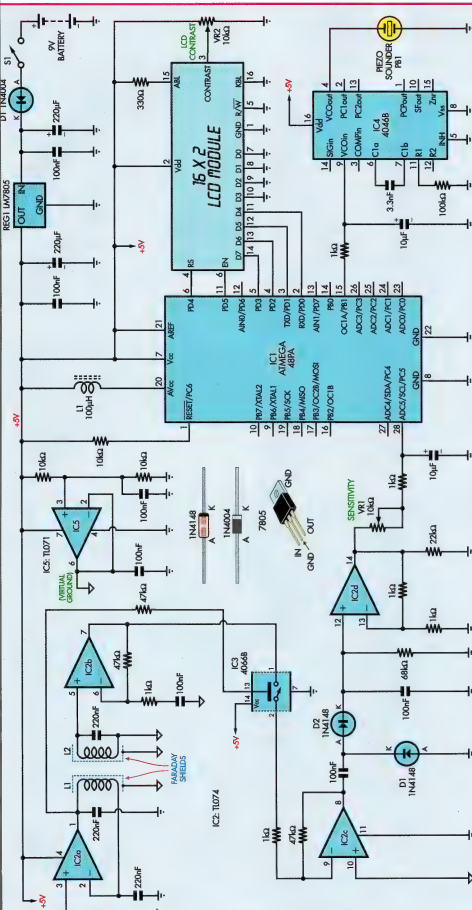


3mm plywood. Mount L1 and L2 with about 25mm overlap between the coils, to form the search head for the detector.

The software is written in BASIC and can be compiled to a HEX file using BASCOM for Atmel AVR. A zip file can be downloaded from the SILICON CHIP website containing both the BASIC source code and HEX file. You will need an Atmel programmer to load the HEX file into a blank ATmega48 microcontroller.

To check out and use the detector, set VR1 to its midpoint. Place the search head well away from any metal object and switch on. You should get a reading above 2.5V and the piezo sounder should produce a tone.

Slowly move the top coil back and forth until the voltage indicator shows 2.40-2.45V and you should hear the audio output "motorboat" with a frequency of around 10Hz.

Now fix the coils in this position and bring a metal object close to the overlapping portion of the search-head. The voltage reading should increase and you should notice a sharp increase in the frequency of the tone produced.

If instead you get a reduction in the voltage and the sounder falls silent, flip the top coil over and repeat this procedure.

Having adjusted the coils, turn VR1 up to set the voltage indicator to 2.5V first, and then higher. The frequency of the sound should sharply increase to around 500 Hz at 2.5V and step by step higher, up to 2.5kHz as you keep on turning up the pot. For maximum sensitivity, set the idle voltage to 2.49V.

Now bring a large coin close to the overlapping portion of the search head, which is its most sensitive part. The piezo sounder pitch should increase. The coin will be detected at a distance of 180-200mm in air.

For lower sensitivity, use VR1 to adjust the idle voltage (ie, without any metal objects near the search head) as low as 2V.

Mahmood Alimohammadi, Tehran, Iran. ($70)

Remote Tell-Tale Indicator for garage doors

It's quite easy to forget to close your garage door and if it gives access to your home or the garage contains anything valuable and portable, that could be a big mistake. It's also frustrating if you can't remember whether you closed the door; you then have to go outside and check. This project gives you a convenient way to check whether your garage door(s) are closed while you're still inside.

The transmitter unit is powered from the garage door controller (or a DC plugpack if you have a manually operated door) and uses microswitches or reed switches to sense whether the door(s) are closed or not. It then transmits signals at 433MHz to an indoor unit which displays the door status using four LEDs and also issues warning beeps if you have forgotten to close a door. The whole process is controlled by a pair of PICAXE14M2 microcontrollers.

First, you will need to mount a switch which closes when your garage door(s) close. The simplest method is probably to attach a small magnet to the inside bottom of the door (eg, using epoxy) and then mount a reed switch on the door frame which is adjacent to the magnet when the door is closed. Check the operation of the reed switch using a DMM set to continuity mode.

Alternatively, mount a microswitch on the bottom of the door frame so that its actuator is depressed when the door is closed. You may need to attach a small piece of metal, plastic or timber to the door to press on the microswitch actuator. For single-door garages, place a link across limit switch S2's terminals to prevent unwanted warning beeps.

The transmitter includes two 4N25 optocouplers which isolate the limit switches from the microcontroller pins and prevent any signals inductively coupled into the wiring from damaging IC1.

If either switch is open, current flows from the DC supply via reverse polarity protection diode D1, two series 470Ω current-limiting resistors and through the associated optocoupler LED. This causes one pair of pins on microcontroller IC1 to be pulled low; pins 5 and 6 for limit switch 1 and pins 3 and 4 for limit switch two. Internal pull-up currents on these pins allow the micro to detect when they are pulled low.

IC1 periodically brings pin 8 high to power up the 433MHz transmitter module and then sends eight bytes of Manchester-encoded data, containing the switch states, via pin 11.

The encoded data contains both a 4-byte identity code (PIN) and 4-byte door status code.

For simplicity, the doors are assumed to be open when not sitting at the door close limits.

The default identity code is 2017 but a range of codes can be used (see comments in the source code).

The receiver picks up data from the 433MHz Rx unit on pin 5 of microcontroller IC2 and decodes it, then checks that the received identity code (PIN) is correct before decoding the door status. The state of output pins 8-11 is then updated, driving indicators LED2 to LED5 to display the open or closed position of both doors.

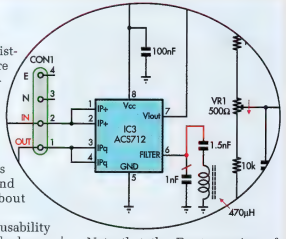
Reduced noise for Isolated Current Probe

This simple modification to the circuit of the Isolated High-Current Adaptor for Scopes & DMMs (August 2012) greatly reduces the RMS noise from the output.

Some time ago I built this project and it works as designed but I noticed an extraneous signal of around 40mV peak-to-peak superimposed on the output of the probe.

The capability of digital scopes to do Fast Fourier analyses and give a frequency spectrum display of the output of the adaptor allowed me to determine that this signal was centred at about 194kHz, which is an artefact of the Allegro ASC712 IC's inbuilt DC-bias correction.

To reduce this noise, I replaced the 1nF filter capacitor at pin 6 with a series-tuned LC circuit as shown in this diagram and it all but eliminated the unwanted 194kHz signal. I used a Jaycar 470µH high-frequency ferrite choke (Cat LF-1108) and a 1.5nF MKT capacitor.



You can fit this to the existing PCB by bending one wire of the inductor and capacitor up and soldering them together, then inserting the whole assembly in place of the 1nF capacitor.

This simple but effective modification maintains the 80kHz bandwidth and reduces the noise to about 30mV peak-to-peak.

This has improved the usability of the adaptor, giving much clearer scope traces, especially at currents below 1A. This modification should be relevant to any project which uses the Allegro Hall effect devices but of course, it depends on a similar internal switching frequency being used.

Ideally, if fitting such a filter to other Allegro devices, you should first do a spectrum analysis of the output, to determine the ideal values for the filter components. I have not tested this on any other device.

Note that the Errata section of the November 2016 issue (on page 104) points out that the "Reinforced Isolation Voltage" rating of the ACS712 does not meet Australian/New Zealand safety standards for double-insulated equipment and so the similar ACS718 device should be used instead in applications where 230VAC mains may be applied to the Adaptor.

Ray Miller,
Currumbin Valley, Qld. ($45)

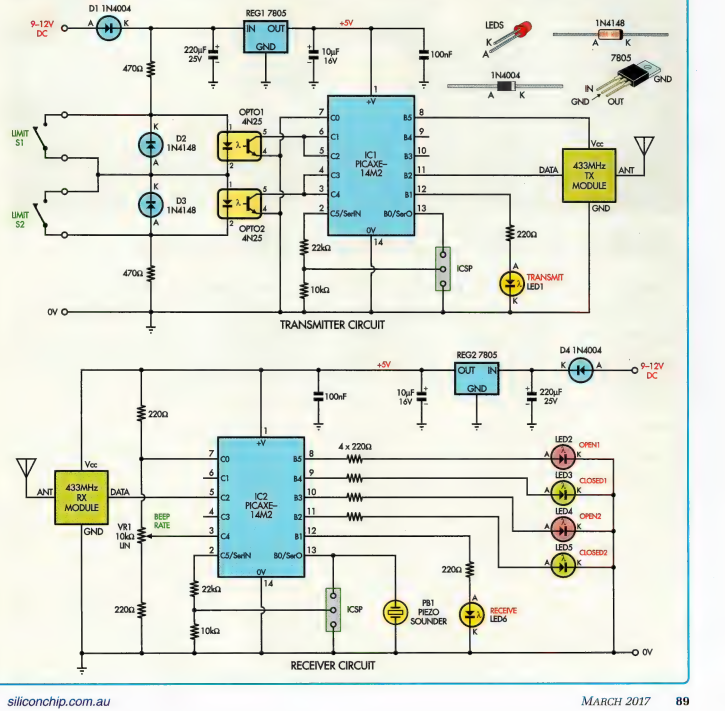
Piezo transducer PB1 (Jaycar AB-3456 or equivalent) is driven by output pin 13 to sound the door open warning beeps. The beep interval (five seconds to five minutes) is set by trimpot VR1, which is only sensed when IC2 is first powered up.

The prototype uses 433MHz transmitter and receiver modules from Jaycar (ZW3100 and ZW3102). You will need to fit an antenna to each module and the simplest antenna is a 170mm length of hook-up wire that may be left straight or coiled into a spiral. PICAXE BASIC commands "rfout" and "rfin" are used to send and receive data; LED1 and LED6 will flash to confirm data is being transmitted or received.

Both the transmitter and receiver units run continually and are best powered by separate 9-12V DC plugpacks, if your garage door controller doesn't have a 12V DC output. It's best to avoid switchmode plugpacks as these can interfere with the 433MHz signal. Each plugpack drives a 7805 voltage regulator which supplies 5V DC to the PICAXE14M2 microcontrollers. The circuits also include 1N4004 diodes for reverse polarity protection.

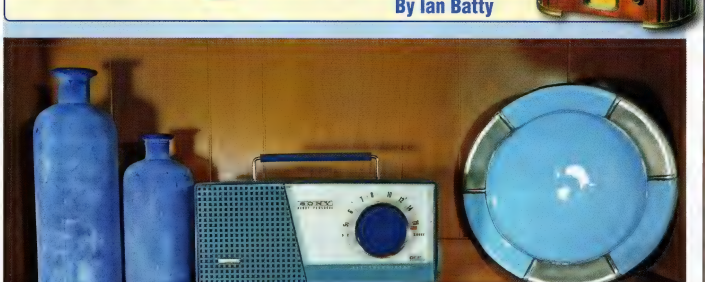
Use the ICSP headers to upload "gd_display_14m2.bas" into both microcontrollers. This program is available for download from the SILICON CHIP website, free to subscribers. You will need a PICAXE-compatible USB cable and a copy of the free program editor from the PICAXE website. The software checks the voltage on pin 7 to determine whether it should operate as the transmitter or receiver unit.

Ian Robertson,
Engadine, NSW. ($60)



Vintage Radio

By Ian Batty



Sony's TR-712 Mantel Radio

Sony's little mantel set, the TR-712, was a major step forward in performance for transistor radios. Previous models from Sony and other companies could only be regarded as having average sensitivity, at best. Then Sony changed the game with this 7-transistor set.

In Sony's earliest days, the company then known as Tokyo Tsushin Kogyo took a massive leap of faith when Masaru Ibuka looked at the potential for transistor-equipped consumer goods. Ibuka had been advised that transistors of the time were only suitable for hearing aids. But he and his engineers had already showed imagination and enterprise by pioneering the use of valve-equipped tape recorders in schools and classrooms.

Summing up a discussion with his fellow engineers, he famously stated "Let's make radios. As long as we're going to produce transistors, let's make them for a product that anyone can afford to buy."

I've reviewed some eighteen sets so far: English, American, German, Australian and Japanese. With a few more on the bench ready to have articles written about them, nothing I've yet seen can match this modestly-styled set from Sony for sensitivity.

Sony's first radio, the rare TR-55, used only five transistors with a Class-A output stage.

Following that, the Sony TR-63 was more ambitious and it became the classic 6-transistor "trannie". While it was a triumph of miniaturisation and wildly successful with some 100,000 imported to the USA alone, the TR-63 was a pocket set, a personal radio and not particularly sensitive. (see the January 2016 issue: www.siliconchip.com.au/Issue/2016/January/Sony%E2%80%99s+TR-63+shirt-pocket+transistor+radio).

By that time, the market was ready for a mantel/table set. It would need good output power and sensitivity, to look good and perhaps be battery-powered. Sony's first effort was the TR-72, a fine-but-pedestrian timber-cased set similar to Stromberg-Carlson's, previously reviewed, 78T11 in the July 2015 issue (See www.siliconchip.com.au/Issue/2015/July/Stromberg-Carlson%E2%80%99s+78T11-79T11+transistor+set).

Then Sony produced the TR-712. Housed in a modest, stylish

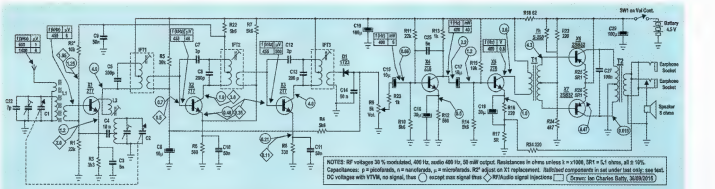


Fig.1: this circuit diagram is for one version of the Sony TR-712 radio. It uses five NPN transistors in the front end (X1-X5) and two PNP transistors in the push-pull output stage (X6 and X7).

plastic cabinet, it has that late 1950s styling with a hint of Japanese influence.

The main dial is reverse printed into the faceplate on the right-hand side. This means that while minor scuffs may blemish the front, all lettering remains safely protected. The large tuning knob drives the gang through a 6:1 reduction gear, allowing easy fingertip tuning.

Interestingly, the dial sports US CONELRAD markers at 640 and 1240kHz. *(Editor's note: this is an artefact of Cold War paranoia in the USA. CONELRAD [Control of Electromagnetic Radiation] was a method of emergency broadcasting to the public of the USA in the event of enemy attack between 1951 to 1963).*

The TR-712 features a "new" Sony logo, with the classic Times Roman lettering adopted in 1961 and retained to this day with minor changes. The above-mentioned article on the TR-63 shows the original "lightning bolt" logo used in 1957 by what was then Totsuko.

The case appears rectangular but subtle curves in the top and bottom relieve what could have been a "shoe-box" effect. It also sounds quite good, with a 5-inch speaker in the cabinet of reasonable size.

Circuit description

My sample TR-712 set uses five NPN transistors in the front end and two PNPs in the push-pull output stage. All the transistors were made by Sony. Have a look at the circuit in Fig.1.

X1 is the frequency converter and it uses collector-base feedback via a 10nF capacitor, C4, from the secondary winding of the local oscillator transformer, L2 (to provide oscillation). While this works just fine, attempting to inject a signal directly at the base for testing stops the oscillation. So my circuit measurements were made with signal injection at the conveniently-provided aerial coupling coil, L1.

The tuning gang uses cut plates, removing the need for a padder capacitor. The plates are also elliptical, rather than semicircular. This reduces "cramping" at the top end of the broadcast band, spreading out those stations and provides easier tuning. The earlier TR-63 lacked this refinement.

The first IF transformer, IFT1, uses a tuned, tapped primary with an untuned secondary. X1's base bias circuit, involving R2, appears combined with the dropping resistor for the 1st IF amplifier X2. X2's collector current (and thus the voltage drop across collector resistor R22) will change with AGC action.

Since changes in a converter's biasing commonly changes the local oscillator operation, does the TR-712's AGC actually affect the converter? In fact, it does, as discussed later.

X2, the first IF amplifier stage, drives IFT2 and gets its bias via the voltage divider consisting of resistors R5 & R4, with the bottom end of R4 going to demodulator/AGC diode D1. This stage is neutralised by 3pF capacitor C7, from the primary winding of IFT2.

As with IFT1, the second IF transformer IFT2 also uses a tapped, tuned primary with an untuned secondary.

The secondary winding of IFT2 drives the base of transistor X3 and provides its base bias from the emitter of transistor X2. While X3 drives IFT3's tapped tuned primary. IFT3's untuned, untapped secondary feeds demodulator diode D1's cathode.

D1's anode delivers demodulated audio (filtered by C14) to volume control R9. It also delivers the AGC voltage, via R4, to the base bias circuit of X2. Audio signals on the AGC line are filtered out by 10µF capacitor C6.

X3 is also neutralised, by a 2pF capacitor, from the primary winding of IFT3.

The AGC control appears as a voltage drop at X2's base, from weak to strong signals. The actual change is not large but voltage divider R7-R6 is holding the emitter fairly constant. Given this, X2's base voltage drop from about 0.7 to 0.5V takes it to quite a low collector current.

As X2's emitter current falls, its emitter voltage does drop by some 100mV. This drop, conveyed to the base of X3, also reduces its bias and gain; the fall in X3's emitter voltage confirms this.

X2's collector voltage, dropped from full supply by R22, rises with AGC action (from weak to strong signals). As noted above, this also affects converter X1, with its collector current rising some 60%.

Audio from the volume control R9 is coupled via capacitor C15 to the base of the first audio transistor, X4. It's a conventional combination-bias circuit, with top cut feedback applied from its collector to base via C23.

X4 feeds the second audio transistor X5, the audio driver. Also using combination bias, its collector load is the primary winding of the audio driver transformer, T1. Its tapped secondary supplies out-of-phase signals to output transistors X6 and X7, to give push-pull Class-B operation.

While Fig.1 shows the output

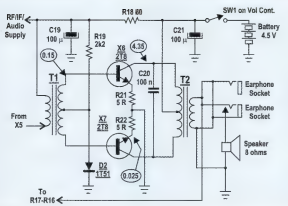


Fig.2: this shows a variant of the TR-712 that replaced the PNP transistors used for X6 and X7 with 2T8 NPN transistors. The thermal compensation was also changed to a more effective circuit using diode D2 instead of the thermistor Th used in Fig.1.

transistors as PNP types, some circuits found online of the TR-712 show them with NPN output transistors and as it happens, my second sample of the set does have NPN 2T8 transistors as shown in the partial circuit of the alternative output stage in Fig.2.

Either way, the output stage operates in conventional Class B, with temperature compensation supplied by thermistor Th in Fig.1 and with R19 supplying a more effective 1T51 bias diode in the case of Fig.2.

Both circuits have further top cut applied by a 100nF (C27/C20) capacitor across the push-pull primary of output transformer T2. T2's secondary connects via earphone sockets, to the 5-inch speaker.

In fact, two sockets are provided: the upper one parallels the earphone with the internal speaker, leaving it in circuit. The lower socket supplies output to the earphone only.

Cleaning it up

The cabinet responded well to a gentle scrub and a polish but as far as the circuit was concerned, more work was needed. The volume control and tuning were both very scratchy.

Cleaning the gang's grounding spring and lubricating the bearings cleared the tuning problems but the volume control was more difficult. It refused to turn down to zero volume and cut out above about 80% rotation.

Disassembly of the volume control potentiometer revealed some kind of insulating deposit on the carbon track and no amount of cleaning would remove it.

As well, the track showed a resistance value of 10kΩ rather than the circuit value of 5kΩ. That was fixed by "poaching" a working pot from my other TR-712 which is now my "parts" set.

The set now performed well on the ferrite antenna but the direct aerial connection needed a lot of signal. Careful examination showed a corroded lead on the coupling coil. Fixing this brought the set into full operation.

The main dial for this set is reverse printed into the faceplate protecting the lettering from damage. The US CONELRAD markers can be seen in red at 640 and 1240kHz. These were relevant only in the USA where they could be used to receive emergency broadcasts.

Performance

How good is it? Answer: surprisingly good! For a 50mW output, it needs only 9µV/m at 600kHz and 20µV/m at 1400kHz. In fact, I was scratching my head at these outstanding figures. But the respective signal-to-noise (SNR) ratios tell the story: 4dB and 6dB.

For more usual SNR values, it needs 30µV/m at 600kHz (for 15dB) and 50µV/m for 20dB at 1400kHz.

At the antenna terminal, it needs only 1µV at 600kHz (0.5µV at 700kHz!) and 6µV at 1400kHz for SNR ratios of 4dB and 5dB. This is shown in the diagram of Fig.3.

For the usual 20dB ratios, it needs 2µV and 25µV, respectively.

The fall-off in gain above 1MHz implies some input mismatching to my standard dummy antenna at the high end of the band.

All that said, I took it outside one evening and tried to find a quiet spot on the dial. Tucked away up here near Castlemaine, I found it impossible not to pick up some station right across the tuning range.

Its IF bandwidth is ±1.6kHz at -3dB down and ±25kHz at -60dB down. The AGC allows some 6dB rise in audio output for a 35dB signal increase, and I was unable to force

it into overload at any reasonable signal level.

Audio response from antenna to speaker is 140Hz to 1700Hz. From volume control to speaker, it's 150~3600Hz.

At 50mW, harmonic distortion is around 6% while clipping occurs at 130mW with distortion of 10%. At 10mW output, harmonic distortion is 7%. Given the feedback in the audio circuit, it's likely the output transistors have drifted and were no longer matched correctly.

At low battery, crossover distortion is obvious on the oscilloscope: maximum output is just 30mW at clipping, with some 9% at 10mW output.

And that link between the AGC circuit (via R22) and the converter's bias? Yes, as shown on the diagram, the converter's emitter voltage (and thus its collector current) does increase on strong signals.

Transistor AGC usually relies on gain falling with lower collector currents. But gain also falls at higher collector currents – it's known as forward AGC.

A test that mimicked this rise showed that the converter's gain fell with increasing bias.

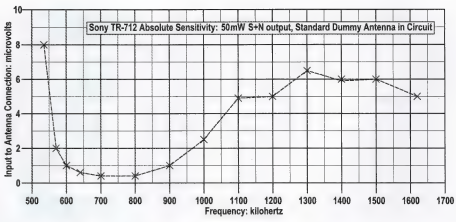


Fig.3: this graph shows the input signal needed at the input terminals to achieve a 50mW audio output from the loudspeaker. This is a very sensitive radio, considering the early development of stage transistors at that time.

One set of circuit notes stated that "converter gain falls with reduced injection voltage", and this is certainly true. That would qualify as a reverse AGC action.

The TR-712 circuit, however, shows a rise of injection voltage with rising X1 bias. So as the effect of X1's unusual bias circuit is to reduce gain by increasing collector current as the AGC takes control of the converter, this is a forward AGC circuit.

It does shift the local oscillator frequency, as I'd expected, by about 1kHz at the low end of the band. Since this only happens with strong signals, there's no obvious detuning effect.

Gain versus noise figure

The TR-712's outstanding sensitivity comes at a price though; a high noise level. It's a reminder that any set's first stage determines the overall performance.

The rear view of the Sony TR-712. To replace the dry cell battery in the set, the back cover needs to be removed.

Transistor noise, like that in valves, comes partly from random emission of charge carriers (electrons, electrons/holes). But there's also the random diffusion of charge carriers across the base.

In addition, a transistor's base exhibits intrinsic resistance, r_{bb}. The base is lightly doped, giving high resistance and it's very, very thin; also a recipe for high resistance.

In combination, this r_{bb} can be some hundreds of ohms and like any resistive component, is a noise source. Prior to advanced diffusion techniques used in Mesa and Planar devices, transistor noise figures, as this set shows, were high.

Theoretically, the TR-712 should give a noise figure of some 22dB at 0.5μV input.

Output transistor matching

Even with the negative feedback from the secondary of the output transformer to the emitter of transistor X5, this set gave high distortion. Mismatched output transistors would be the main suspect.

So the question was how to improve the distortion performance, without being able to get replacement output transistors? I tried adding a feedback resistor from collector to base on one of the output transistors. Sure enough the distortion fell.

The effect was greater with transistor X6, so I concentrated on it. Finishing with a 1.8kΩ resistor in series with a 47μF capacitor, I was able to get distortion under 2% at 50mW and about 1.2% at 20mW.

Yes, it does reduce the set's gain but it would be a useful fix where you've got noticeable distortion and no replacement transistors.

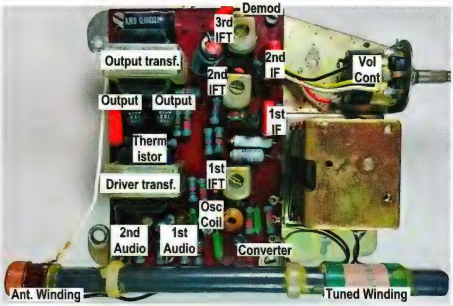
Would I buy another? There's a TR-712B that sports medium wave and shortwave. If you see one become available, snap it up before I hear about it!

Given my TR-712's outstanding performance, I reckon the 712B will be one hot set on both bands.

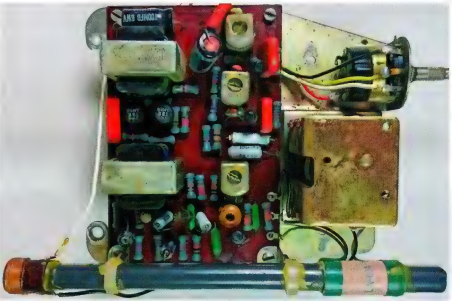
Special handling

The dial pointer sits between the transparent faceplate and the white backing panel. Chassis removal demands that you carefully slide the pointer off its shaft. I made a mini "tyre lever" by bending the end of a stout piece of wire, then eased the pointer's hub forward as I drew the chassis out backwards.

To replace it, find a piece of tubing a little larger than the tuning shaft and gently press the pointer hub into place as you reinsert the chassis. Make sure the gang is fully closed (or open) so you can set the pointer.



This labelled picture of the main PCB shows the position of the major components. Note that this is the earlier version with the thermistor used for stabilisation of the push-pull amplifier's quiescent current.



TR-712 versions

Several cabinet colours exist, all in low-key renderings. There's a blue one on YouTube, an off-white/bone TR-712B (and many other Sony sets) at Radiokobo, a beige TR-712B at Jinkei, and my classic olive green parts set at RadioMuseum. SC

Further Resources

Further information on the set can be found as follows:

On YouTube at: www.youtube.com/watch?v=IK7NPchbaTo

On Radiokobo at: http://radio-kobo.sakura.ne.jp/G/tr-radio1/sony.html

On Jinkei at: www.geocities.jp/jnkei/soni-radio/tr-712b.html

TR-712 and 712B Circuits are available from Kevin Chant at www.kevinchant.com and don't forget RadioMuseum at www.radiomuseum.org

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LED LADYBIRD	APR 2013	08103131	$5.00
CLASSIC-D 12V to ±35V DC/DC CONVERTER	MAY 2013	11104131	$15.00
DO NOT DISTURB	MAY 2013	12104131	$10.00
LF/HF UP-CONVERTER	JUN 2013	07106131	$10.00
10-CHANNEL REMOTE CONTROL RECEIVER	JUN 2013	15106131	$15.00
IR-TO-455MHZ UHF TRANSCEIVER	JUN 2013	15106132	$7.50
"LUMP IN COAX" PORTABLE MIXER	JUN 2013	01106131	$15.00
L1L PULSER MKII TRAIN CONTROLLER	JULY 2013	09107131	$15.00
L1L PULSER MKII FRONT & REAR PANELS	JULY 2013	09107132/3	$20.00/set
REVISED 10 CHANNEL REMOTE CONTROL RECEIVER	JULY 2013	15106133	$15.00
INFRARED TO UHF CONVERTER	JULY 2013	15107131	$5.00
UHF TO INFRARED CONVERTER	JULY 2013	15107132	$10.00
IPOD CHARGER	AUG 2013	14108131	$5.00
PC BIRDIES	AUG 2013	08104131	$10.00
RF DETECTOR PROBE FOR DMMs	AUG 2013	04107131	$10.00
BATTERY LIFESAVER	SEPT 2013	11108131	$5.00
SPEEDO CORRECTOR	SEPT 2013	05109131	$10.00
SDRADIO (INTEGRATED SDR) Main PCB	OCT 2013	06109131	$35.00
SDRADIO (INTEGRATED SDR) Front & Rear Panels	OCT 2013	06109132/3	$25.00/pr
TINY TIM AMPLIFIER (same PCB as Headphone Amp [Sept11])	OCT 2013	01309111	$20.00
AUTO CAR HEADLIGHT CONTROLLER	OCT 2013	03111131	$10.00
GPS TRACKER	NOV 2013	05112131	$15.00
STEREO AUDIO DELAY/DSP	NOV 2013	01110131	$15.00
BELLBIRD	DEC 2013	08112131	$10.00
PORTAPAL-D MAIN BOARDS	DEC 2013	01111131-3	$35.00/set
(for CLASSIC-D Amp board and CLASSIC-D DC/DC Converter board refer above [Nov 2012/May 2013])			
LED Party Strobe (also suits Hot Wire Cutter [Dec 2010])	JAN 2014	16101141	$7.50
Bass Extender Mk2	JAN 2014	01112131	$15.00
Li'l Pulser Mk2 Revised	JAN 2014	09107134	$15.00
10A 230VAC MOTOR SPEED CONTROLLER	FEB 2014	10102141	$15.00
NICAD/NIMH BURP CHARGER	MAR 2014	14103141	$15.00
RUBIDIUM FREQ. STANDARD BREAKOUT BOARD	APR 2014	04105141	$10.00
USB/RS232C ADAPTOR	APR 2014	07103141	$5.00
MAINS FAN SPEED CONTROLLER	MAY 2014	10104141	$10.00
RGB LED STRIP DRIVER	MAY 2014	16105141	$10.00
HYBRID BENCH SUPPLY	MAY 2014	18104141	$20.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	JUN 2014	01205141	$20.00
TOUCHSCREEN AUDIO RECORDER	JUL 2014	01105141	$12.50
THRESHOLD VOLTAGE SWITCH	JUL 2014	98106141	$10.00
MICROMITE AS/SPI VIDEO TERMINAL	JUL 2014	24107141	$7.50
FREQUENCY COUNTER ADD-ON	JUL 2014	04105141a/b	$15.00
TEMPMASTER MK3	AUG 2014	21108141	$15.00
44-PIN MICROMITE	AUG 2014	24108141	$5.00
OPTO-THEREMIN MAIN BOARD	SEP 2014	23108141	$15.00
OPTO-THEREMIN PROXIMITY SENSOR BOARD	SEP 2014	23108142	$5.00
ACTIVE DIFFERENTIAL PROBE BOARDS	SEP 2014	04107141/2	$10/SET
MINI-D AMPLIFIER	SEP 2014	01110141	$5.00
COURTESY LIGHT DELAY	OCT 2014	05109141	$7.50
DIRECT INJECTION (D-I) BOX	OCT 2014	23109141	$5.00
DIGITAL EFFECTS UNIT	OCT 2014	01110131	$5.00
DUAL PHANTOM POWER SUPPLY	NOV 2014	18112141	$10.00

PRINTED CIRCUIT BOARD TO SUIT PROJECT:	PUBLISHED:	PCB CODE:	Price:
REMOTE MAINS TIMER	NOV 2014	19112141	$10.00
REMOTE MAINS TIMER PANEL/LID (BLUE)	NOV 2014	19112142	$15.00
TINE-CHIP AMPLIFIER	NOV 2014	01109141	$5.00
TDR DONGLE	DEC 2014	04112141	$5.00
MULTISPARK CDI FOR PERFORMANCE VEHICLES	DEC 2014	05112141	$10.00
CURRAWONG STEREO VALVE AMPLIFIER MAIN BOARD	DEC 2014	01111141	$50.00
CURRAWONG REMOTE CONTROL BOARD	DEC 2014	01111144	$5.00
CURRAWONG FRONT & REAR PANELS	DEC 2014	01111142/3	$30/set
CURRAWONG CLEAR ACRYLIC COVER	JAN 2015	-	$25.00
ISOLATED HIGH VOLTAGE PROBE	JAN 2015	04108141	$10.00
SPARK ENERGY METER MAIN BOARD	FEB/MAR 2015	05101151	$10.00
SPARK ENERGY ZENER BOARD	FEB/MAR 2015	05101152	$10.00
SPARK ENERGY METER CALIBRATOR BOARD	FEB/MAR 2015	05101153	$5.00
APPLIANCE INSULATION TESTER	APR 2015	04103151	$10.00
APPLIANCE INSULATION TESTER FRONT PANEL	APR 2015	04103152	$10.00
LOW-FREQUENCY DISTORTION ANALYSER	APR 2015	04104151	$5.00
APPLIANCE EARTH LEAKAGE TESTER PCBs (2)	MAY 2015	04203151/2	$15.00
APPLIANCE EARTH LEAKAGE TESTER LID/PANEL	MAY 2015	04203153	$15.00
BALANCED INPUT ATTENUATOR MAIN PCB	MAY 2015	04105151	$15.00
BALANCED INPUT ATTENUATOR FRONT & REAR PANELS	MAY 2015	04105152/3	$20.00
4-OUTPUT UNIVERSAL ADJUSTABLE REGULATOR	MAY 2015	18105151	$5.00
SIGNAL INJECTOR & TRACER	JUNE 2015	04106151	$7.50
PASSIVE RF PROBE	JUNE 2015	04106152	$2.50
SIGNAL INJECTOR & TRACER SHIELD	JUNE 2015	04106153	$5.00
BAD VIBES INFRASOUND SNOOPER	JUNE 2015	04104151	$5.00
CHAMPION + PRE-CHAMPION	JUNE 2015	01109121/2	$7. 50
DRIVEWAY MONITOR TRANSMITTER PCB	JULY 2015	15105151	$10.00
DRIVEWAY MONITOR RECEIVER PCB	JULY 2015	15105152	$5.00
MINI USB SWITCHMODE REGULATOR	AUG 2015	18107151	$5.00
VOLTAGE/RESISTANCE/CURRENT REFERENCE	AUG 2015	04108151	$2.50
LED PARTY STROBE MK2	AUG 2015	16101141	$7.50
ULTRA-LD MK4 200W AMPLIFIER MODULE	SEP 2015	01107151	$15.00
9-CHANNEL REMOTE CONTROL RECEIVER	SEP 2015	15106151	$15.00
MINI USB SWITCHMODE REGULATOR MK2	SEP 2015	18107152	$5.00
2-WAY PASSIVE LOUDSPEAKER CROSSOVER	OCT 2015	01205141	$20.00
ULTRA LD AMPLIFIER POWER SUPPLY	OCT 2015	01109111	$15.00
ARDUINO USB ELECTROCARDIOGRAPH	OCT 2015	07108151	$7.50
FINGERPRINT SCANNER – SET OF TWO PCBS	NOV 2015	03109151/2	$15.00
LOUDSPEAKER PROTECTOR	NOV 2015	01110151	$10.00
LED CLOCK	DEC 2015	19110151	$15.00
SPEECH TIMER	DEC 2015	19111151	$15.00
TURNTABLE STROBE	DEC 2015	04101161	$5.00
CALIBRATED TURNTABLE STROBOSCOPE ETCHED DISC	DEC 2015	04101162	$10.00
VALVE STEREO PREAMPLIFIER – PCB	JAN 2016	01101161	$15.00
VALVE STEREO PREAMPLIFIER – CASE PARTS	JAN 2016	01101162	$20.00
QUICKBRAKE BRAKE LIGHT SPEEDUP	JAN 2016	05102161	$15.00
SOLAR MPPT CHARGER & LIGHTING CONTROLLER	FEB/MAR 2016	16101161	$15.00
MICROMITE LCD BACKPACK, 2.4-INCH VERSION	FEB/MAR 2016	07102121	$7.50
MICROMITE LCD BACKPACK, 2.8-INCH VERSION	FEB/MAR 2016	07102122	$7.50
BATTERY CELL BALANCER	MAR 2016	11111161	$6.00
DELTA THROTTLE TIMER	MAR 2016	05102161	$15.00
MICROWAVE LEAKAGE DETECTOR	APR 2016	04103161	$5.00
FRIDGE/FREEZER ALARM	APR 2016	03104161	$5.00
ARDUINO MULTIFUNCTION MEASUREMENT	APR 2016	04116011/2	$15.00
PRECISION SIGNZAI TURNTABLE DRIVER	MAY 2016	04104161	$15.00
RASPBERRY PI TEMP SENSOR EXPANSION	MAY 2016	24104161	$5.00
100DB STEREO AUDIO LEVEL/VU METER	JUN 2016	01104161	$15.00
HOTEL SAFE ALARM	JUN 2016	03106161	$5.00
UNIVERSAL TEMPERATURE ALARM	JULY 2016	03105161	$5.00
BROWNOUT PROTECTOR MK2	JULY 2016	10107161	$10.00
8-DIGIT FREQUENCY METER	AUG 2016	04105161	$10.00
APPLIANCE ENERGY METER	AUG 2016	04116061	$15.00
MICROMITE PLUS EXPLORE 64	AUG 2016	07108161	$5.00
CYCLIC PUMP/MAINS TIMER	SEPT 2016	10108161/2	$10.00/pair
MICROMITE PLUS EXPLORE 100 (4 layer)	SEPT 2016	07109161	$20.00
AUTOMOTIVE FAULT DETECTOR	SEPT 2016	05109161	$5.00
MOSQUITO LURE	OCT 2016	25110161	$5.00
MICROPOWER LED FLASHER	OCT 2016	16109161	$5.00
MINI MICROPOWER LED FLASHER	OCT 2016	16109162	$2.50
50A BATTERY CHARGER CONTROLLER	NOV 2016	11111161	$10.00
PASSIVE LINE TO PHONO INPUT CONVERTER	NOV 2016	01111161	$5.00
MICROMITE PLUS LCD BACKPACK	NOV 2016	07110161	$7.50
AUTOMOTIVE SENSOR MODIFIER	DEC 2016	05111161	$10.00
TOUCHSCREEN VOLTAGE/CURRENT REFERENCE	DEC 2016	04110161	$12.50
SC200 AMPLIFIER MODULE	JAN 2017	01108161	$10.00
60V 40A DC MOTOR SPEED CON. CONTROL BOARD	JAN 2017	11112161	$10.00
60V 40A DC MOTOR SPEED CON. MOSFET BOARD	JAN 2017	11112162	$12.50
GPS SYNCHRONISED ANALOG CLOCK	FEB 2017	04202171	$10.00
ULTRA LOW VOLTAGE LED FLASHER	FEB 2017	16110161	$2.50

NEW THIS MONTH

POOL CAR COUNTER	MAR 2017	19102171	$15.00
STATIONMASTER TRAIN CONTROLLER	MAR 2017	09103171/2	$15.00/set

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ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Pixels ain't pixels

Based on the review by Kevin Poulter in your August 2015 edition, I bought a Nikon P900 digital camera. Despite the fact that it is rated as having 16 megapixels, the best photo I can get contains only about 4 megapixels.

I took the camera back to the shop and they insist the camera is set to capturing maximum photo detail. I notice this also occurs with several other digital cameras I have. I can find no explanation online for why this is. Are we not being told something?

Does a digital camera use one pixel for light intensity, and one for each of the fundamental colours (red, blue, green) and thus for each pixel in the final photo you need four on the sensor? And if this is so why don't they say so? (C. K., via email)

● SILICON CHIP photographer Ross Tester comments: the file size you're quoting is not megapixels (MP) but megabytes (MB) – and there is no direct relationship between megapixels and file size (megabytes). Even if there were, it would depend a lot on the processing and/or compression done inside the camera and the recorded photo format – RAW, TIFF, JPEG (and there are several types/standards there) and so on.

When a camera image size is quoted in megapixels, that's simply the number of elements its image capturing sensor has. In the case of your Nikon P900, that is 4608 x 3456 pixels or just on 16 million. But the Nikon P900 cannot capture the image in RAW format – it compresses it significantly to achieve the 4MB file size as a .JPG file.

Even with today's monster memory cards, you can go through a lot of cards saving RAW files. However, for professionals (who will do most of their processing off-camera via Photoshop, etc), that's what they will do.

But unless you want the absolutely best possible resolution (say to crop to a tiny area, or enlarge to a poster-size print, or larger) the JPG format should suffice in 99% of cases. And with the other benefits of the P900, you're probably going to be more than satisfied.

Having said all that, do keep in mind that most digital camera sensors are only able to sense a single colour for each pixel (red, green or blue) so compared to, say, a monitor, where each pixel consists of red, green AND blue, to compare the resolutions directly you should mentally halve the camera resolution.

In other words, the image from a 16-megapixel camera should look sharp on any monitor up to about 8 megapixels, such as a 4K monitor (3840 x 2160).

By the way, just like you, on the basis of Kevin Poulter's article, I also bought a Nikon P900!

5-Element FM Broadcast Antenna size

Just a query for the 5-element FM Antenna published in the October 2016 issue. On page 73, the folded dipole (B-B) is shown as 1440mm but below it's shown as 1400mm. Which is it? (J. P., via email)

● Sorry about that discrepancy. The difference is immaterial but it should be 1400mm.

Problems with UHF Remote Control

I'm hoping you may be able to shed some light on a problem I'm having with the Versatile 10 Channel Remote Control Receiver from the June & July 2013 issues of SILICON CHIP. I originally built this project back in 2013 and did the modification to the Altronics A1012 remote control unit by adding the IR-to-RF board.

From the outset, the infrared side of things worked perfectly. But I really need the link to be RF so that I can use it to control my evaporative air conditioner from anywhere in the house.

Since I could not get it to work correctly back then, I put it aside until I had some time to re-visit it recently.

Overload protection for mains winch motor

I have an old winch, which pulls up a ski boat. In the shaft at one point there was a brass keyway which was designed to break under strain.

Recently, it did just that but I then had difficulty repairing it properly and as a result, it no longer has this safety feature. The motor is heavily geared so some protection is needed; if the ski boat snagged and the stainless steel cable snapped, it could cause someone a serious injury.

The motor is powered from a single-phase 230VAC supply. Can you recommend a variable power overload device that can be inserted between the power supply and motor, that will cut out under excessive load?

I am thinking it should be variable so I can set the cut-out threshold to be just above the current level where it normally operates, for fast tripping in case the trolley is jammed or derails. (R. A., Toronto, NSW)

● Adjustable motor protection circuit breakers are available but they are not cheap; see **http://siliconchip.com.au/l/aac4**

You could use a standard circuit breaker such as those from Altronics (cat S5503 to S5535 [3 to 35A]). You may find S5503 (3A) or S5505 (5A) suitable. Or alternatively, use one of the S5553-S5557 (3-7A) types.

These trip at twice their rated current after one minute, or much faster at a higher overload, and may be sufficient to allow the motor to start up without tripping.

The circuit breaker and wiring would need to be placed in a suitable box and with the wiring secured properly.

I have the Mk1 PCB and so the specified track was cut (and tested), the insulated wire link fitted and the PIC reprogrammed with the updated firmware. On the transmitter board fitted to the remote control, I changed the 100Ω resistor to 22Ω. I used the Jaycar transmitter and receiver units.

I found that reception via the RF link was extremely unreliable at best, with no more than about 2~3m of range and intermittent operation. Both antennas are 170mm long.

I tested the unit by removing the infrared receiver and bridging pins 1 & 2 as stated in the article. Later, I re-fitted the infrared receiver and once again the unit worked perfectly, so I think there must be a problem with the RF transmitter and/or receiver.

I purchased a Tx/Rx set from Altronics, built a completely new remote control IR-to-RF board (with a 27Ω resistor fitted in place of the 100Ω) and fitted it to the A1012 remote control as well as fitting the new receiver to the remote control receiver board. This only made matters worse! The infrared side of the things still work perfectly but I got absolutely no response via the RF link.

Do you know if anybody else has had this sort of problem? Do you have any suggestions as to what I can try next? I know the remote control board is working as it should; I use it to control the 20W Class-A amplifier that I built last year and the LED clock from the November 2015 and January 2016 issues. The codes are configured correctly for use with this project. The "set" jumper on the board has been removed. Any suggestions appreciated. (P. C., Woodcroft, SA)

- The Altronics UHF receiver is different to the Jaycar UHF receiver in that pin 3 for the Altronics version is an analog output and pin 2 the digital output.

For the Jaycar receiver, both pins 2 and 3 are digital outputs. We have catered for both types by only connecting to pin 2, leaving pin 3 open. Check that pin 3 is not shorted on the PCB with a solder bridge and that the receiver is oriented correctly.

The 100Ω resistor is for supply decoupling for the infrared receiver. You may find the 100Ω resistor decouples its supply better than the 22-27Ω resistor you are using.

Tidal clock project suggestion

I like the GPS Synchronised Analog Clock Driver project in the February 2017 issue. I just hope Jaycar or Altronics will do a kit for it. I will build it if there is a kit for it.

What about removing the hour and seconds hands and re-design the clock face to show high tide and low tide? The software would need to be modified too. This would make a simple tide clock.

You could even add WiFi to read the tide times from the internet, to make a really accurate tide clock. Tide clocks are not commonly available. (R. W., Mount Eliza, Vic)

- We like the suggestion but it would mean a complete redesign, possibly using our Micromite BackPack with a touchscreen LCD panel. We wonder how popular such a project would be, given that you can get tidal info any time of the day from the internet via your smartphone.

Mounting Majestic speakers up high

I have recently been thinking of building a pair of Majestic loudspeakers (June & September 2014) with view to using them in a small/medium sized hall of approximately 16 x 16 metres. My question is whether the placement of the Majestic speakers on the floor is critical to their performance.

To ensure clear listening in a crowded dance floor, I would like to elevate them above the heads of the crowd. I would of course build them with a base plate for this application to get the required "loading" for the bass reflex design without any chuffing, as indicated in the original article.

This leads to the question of which amplifier and power supply to use;

Why a clock motor runs in the correct direction

I am writing in relation to the GPS-synchronised Analog Clock Driver in the February 2017 issue of SILICON CHIP.

As someone who is interested in electronics (I've done physics at both high school and in the first year of my BSc degree) and a subscriber to both SILICON CHIP and Electronics Australia going back to 1974, I still can't understand some of the jargon that is used in articles relating to projects.

As such, am I missing something in relation to the content of the article for the above project when I ask whether it matters how the CON1 connection is made to the motor coil?

Isn't there a positive and negative? If the wires are connected the wrong way around, won't the hands move in the wrong direction, anti-clockwise instead of clockwise, and hence the clock will run backwards? (P. M., Karabar, NSW)

- That's a good question. The first point is that the clock drive waveform is bipolar, so it can be regarded as an AC waveform.

So that means that the polarity of the connecting wires can't matter. But that still does not explain it, does it? Have a look at the diagram of Fig.2 on page 29 of the February 2017 article.

In effect, the second hand is moved in one direction only by the soft iron stator. It acts like a conventional clock escapement. It is not possible for the rotor to move in the wrong direction.

By the way, the mechanical details of crystal clocks tend to vary somewhat, so if you pull a mechanism apart (as you will need to, if you build this clock), you will probably find it looks different from the photo we published on page 28.

In the case of the one we used for our prototype, we found that one of the gears was magnetised (this is the "multi-polar permanent magnet rotor") and this ensures that the mechanism rotates in one direction only.

However, regardless of the exact details of the mechanism, all crystal clocks have the same operating principle and they have a two-wire connection from the driving circuitry, with a bipolar driving waveform.

Champion Amplifier 50Hz buzz and use with piezo pickup

I've just finished building the Champion Amplifier (Silicon Chip, January 2013) from a Jaycar Kit, KC5519. The preamp and amplifier work fine but I have a couple of issues.

1. I have a horrible 50Hz buzz which is obviously coming from the input end of the amplifier. I first suspected it was the plugpack that I was using. I tried it with a 9V battery which gave the same result so it is definitely not mains hum from the power supply.
2. I need to drive this amplifier from a piezo pickup (Jaycar AB2440) mounted in a musical instrument. I understand that I need to increase the input impedance but I do not have the acumen to know which components to change to achieve this. At present, the sound is very metallic with a lot of distortion. I only require one input, so I have shorted the other input (CON2) as suggested in the kit instructions.

I am using 3m of shielded cable with 1/4-inch jack plugs at either end between the instrument and the amplifier. Any suggestions regarding these issues are appreciated. (M. McK., Wellington, NZ)

● We assume the piezo pickup you are using is the Jaycar AB3440 (not the AB2440). A description of how to make this into a pickup for instruments can be found at http://projects.kumpf.cc/projects/GuitarPickup/

You will need to remove the 100pF capacitor that is in parallel with the 2.2MΩ resistor as part of the input of the Champion preamplifier.

If left in place, that capacitor will severely roll off signals above 723Hz at best (or at a lower frequency) when connected to a high impedance source such as a piezo element.

The sound should improve markedly with the capacitor removed. In addition, you would need to take particular attention to the way the transducer is mounted, as in the website article mentioned above for best sound quality.

there are plenty of good choices including your latest SC200 amplifier design (January-March 2017). I have several 50-0-50V toroidal transformers from many years ago as spares for a Mosfet power amplifier from the dark ages. I would like to use these but they obviously deliver a voltage far too high for the SC200.

I am considering unwinding some of the secondary windings from these transformers to reduce the voltage to 45-0-45. Can you see any pitfalls in doing so? (C. G., Albany, WA)

● While you certainly should add a base plate to the enclosure, it will sound different when mounted in an elevated position. Ideally, it should be driven via some sort of DSP unit to give an optimum response in that application.

You can reduce the turns on the secondary which we assume will have been bifilar wound. Make sure that the modified winding is properly insulated for safe operation.

Battery Charger Controller relay query

Regarding the 50A Battery Charger Controller project published in your November 2016 issue, if the charger is turned off during charging, the relay will stay on. Won't this then flatten the battery being charged? (I. C., via email)

● The disconnection of the input supply such as a charger or solar panel is monitored and the relay is switched off by the micro when this occurs.

Do-it-yourself sound bar wanted

I have been a reader since the days of Radio, TV & Hobbies and get the latest Silicon Chip issue from the Gold Coast library at Burleigh. I have not noticed any articles on the construction of a sound bar for those with hearing loss.

Alternatively, could you consider publishing a home theatre system with emphasis on high frequencies and less on the woofer, as is common on most home theatre systems?

It would also be good if you considered publishing a basic electronics course for those new readers of the magazine. Leo Simpson's Publisher's Letters are always appreciated. (M. M., Burleigh Waters, Qld)

● Construction of a sound-bar would not be a viable project since consumer units are available so cheaply. Aldi recently had one at about $80 and there is no way we could design something better or cheaper than that.

We are also not sure that we could do much in tailoring the sound quality to better cater for those with poor hearing since more most people tend to have a very sharp cutoff above a certain frequency and no amount of boosting above that cutoff will do much good.

In fact, we think a pair of wireless headphones would probably be a much better option in those cases because the user can tailor the sound to some extent and also have it as loud as he or she wants it.

We have considered updating the old Basic Radio Course that was produced years ago by Electronics Australia magazine but the job of re-writing it to be bring it up to 2017 would be a mammoth task. If we could find a suitable text book for beginners we would certainly sell it.

Thanks for your comment about the Publisher's Letters.

Inflated capacities for rechargeable cells

I was wondering why Silicon Chip does not design more battery-operated projects using rechargeable cells. For example, I have seen on eBay that you can buy packs of 18650 Li-ion cells out of China for only a few dollars.

With ratings such as 9000mAh and 9800mAh, these would seem to me to offer a really good, long-term supply. And why do you need cells with inbuilt protection? (B. C., via email)

● We've seen those cells advertised too. But like much of the internet, don't believe everything you read. The largest-capacity 18650 cells currently manufactured anywhere in the world (we believe) are Panasonic types rated at 3600mAh.

That makes 9800mAh seem a bit of a stretch. We're not claiming the suppliers are telling porkies but you can easily find any number of YouTube videos with tests showing that most of

Need help finding potentiometers

I'm restoring and enhancing my old ETI4600 synthesiser (www.eti4600synthesiser.org.uk) but I am having trouble sourcing a dozen 2MΩ or 2.2MΩ log pots with/without a DPDT switch. I spent the weekend looking around the web, from Mouser to Digi-Key to Futurlec downwards, with only one likely candidate: http://siliconchip.com.au/l/aac5

No switch though. I looked at Piher, also no switch (www.piher-nacesa.com/pdf/22-T16v03.pdf). I'm waiting for a reply to a query to a distributor, regarding MOQ (minimum order quantity) and so on.

I'm guessing that the demise of valve circuits has led to decreased demand for pots greater than 1MΩ. Alps, Alpha, etc appear to end their range at 1MΩ.

Even companies who have spares for the older valve amps (Marshall, Vox, etc) don't appear to have anything. Do you know of any supplier in Australia or NZ who could help ex-stock?

If push comes to shove, I may have to get 5MΩ pre-sets from Mouser, logarithm-ise them and make some sort of shaft with an actuator that can activate a 4066. (J. C., Auckland, NZ)

- We have no idea where to get such pots and we have also noticed that values above 1MΩ are hard to come by. Perhaps a reader can help.

these 9000 and 9800mAh 18650s are flat out making 1000mAh – some much less! (You'll also find which brands to avoid – most out of China on eBay, it would seem).

Unless a circuit has protection incorporated, we would not consider using unprotected cells. They're there to stop the cell being overcharged or over-discharged, which in the worst case can lead to an explosion and/or fires. Incidentally, expect to pay around $20 for genuine Panasonic, LG, Sanyo, Samsung, Sony or other 18650s rated at (real!) 3000mAh or more.

If you find that a bit steep, you could consider purchasing a 2000mAh-rated Turnigy 18650 cell from HobbyKing for $6.62 or a similar 2500mAh-rated cell for $9.04. We expect those will come close to their rated capacities and they are in stock in their Australian warehouse at the time of writing.

Modifying crankshaft position sensor output

I am interested in your Automotive Sensor Modifier project from the December 2016 issue. I wish to intercept and modify the signal from the crankshaft position sensor to advance the ignition timing to take advantage of higher octane fuel. In my case, the sensor is described as a magnetic reluctance type which delivers an AC pulse. I am unsure of how it could work but if the signal was delayed for 355° of crankshaft rotation then I assume this would give a spark advance of 5°.

Do you have any ideas or projects that would enable manipulation of the firing advance outside that which is pre-mapped in the ECU? Things were much simpler when a timing light and slight rotation of the distributor achieved the same result. (B. S., Killarney Vale, NSW)

- We have published a Programmable Ignition System in the March-May 2007 issues that can be used as an interceptor to alter the spark timing. It takes signal from the distributor and not the crankshaft, so it may not be suitable for your vehicle. You can see a preview of the first part at: www.siliconchip.com.au/Issue/2007/March/Programmable+Ignition+System+For+Cars%3B+Pt.1 There are links from that preview to the previews of the subsequent two parts.

Jaycar used to sell a kit for that project (KC5542/KC5543) but it has been discontinued so we now have the PCBs and programmed PIC in our Online Shop; see www.siliconchip.com.au/Shop/?article=2165

We haven't published a system that reads the crankshaft signal, mainly

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Changing the Ultrasonic Anti-Fouling low battery threshold

I have been a sporadic reader of electronics magazines since the days of Radio, TV & Hobbies and always find them interesting.

I gather that the Versatimer/Switch project described in the June 2011 issue of SILICON CHIP magazine is the latching relay "future project" that was mentioned in your February 2011 MPPT Solar Charge Controller project.

After three weeks of terrible weather some years ago now, the battery on my boat was drawn down by the Ultrasonic Anti-Fouling Unit (SILICON CHIP, September & November 2010) to a point where the MPPT Solar Charge Controller shut down. Running the motor for a while raised the voltage to a level where the Solar Charge Controller restarted.

Plainly, I need to disconnect the Ultrasonic Anti-fouling unit when the 12V lead-acid battery voltage drops below a safe level and reconnect it when the voltage is restored to a safe level. No other timing or trigger functions are required.

Can the Versatimer be configured to perform only the required battery protection function? And when the latching relay is open, how much current is drawn by the Versatimer?

I know the Anti-fouling should run continuously but I have to be pragmatic about it. (D. J., via email)

● Yes, the Versatimer/Switch is the future project which was referred to in the Solar Charge Controller article.

The Ultrasonic Anti-fouling unit does switch off with low battery but it may not be the correct threshold for your application. The threshold is easily changed.

For example, to increase the low-voltage cut-out from 11.5V to 12V, place a 150kΩ resistor across the 10kΩ resistor that connects from pin 5 of IC2 to ground. This changes the resistance of the lower leg of the voltage divider from 10kΩ to 9.375kΩ.

On the PCB, the 10kΩ resistor in question is to the right of the two 22pF capacitors and just below the 10µF capacitor.

When the battery voltage is 12V, this new divider provides 3.83V to pin 5 and this is the switch-off threshold. The battery will need to rise to 12.53V (that's 4V at pin 5) for the anti-fouling unit to start up again.

This in contrast to the original value of 10kΩ providing 11.5V cut-out and 12V restart thresholds. You can vary the 150kΩ value if you want a different threshold; a lower value will give a higher threshold and vice versa.

If you wish to use the Versatimer, it can be used just as a low voltage cut-out switch. To do this, bridge out the test switch and set LK3 to follow mode. VR1 then sets the low battery threshold. The standby current is around 27µA in this configuration.

because engines differ in the way the top dead centre (TDC) is indicated. It can be indicated by either a missing tooth or an extra tooth on the flywheel, which the engine management unit detects.

SC200 transistor substitution question

I was considering building a couple of the SC200 modules and wanted to check if you thought that substituting MJL1302/3281s for the FJA4313OTU/FJA4213OTU output transistors would likely cause any stability problems. On paper they seem close enough other than the higher output capacitance (600pF) of the MJLs. I have plenty of these and would prefer to use them if possible.

I also noticed that mounting the output inductor vertically was able to provide a lower distortion in both the SC200 and the Ultra-LD Mk.4 amp modules. Would this mod work on the Ultra-LD Mk.3 amplifier modules as well, since I have built some of these previously? (G. J., Stafford, Qld)

● We're not sure what you mean by transistor output capacitance. It is likely that the transistors you are referring to will work in this circuit but we have not tried them. If you have them on hand, you have little to lose by giving them a go. The main reason we went with the Fairchild transistors over the On Semiconductor types is that they have similar performance at a lower price.

There's a slight possibility that a change to the inductor orientation (as in the SC200) will give an improvement in the Ultra-LD Mk.3 but that can only be verified by a test using a distortion analyser.

We think it's unlikely as the horizontally mounted inductor in that design actually appeared to partially cancel the magnetic field due to current flowing in the PCB tracks. We commend you stick with the orientation described in the original project.

Cable problems with SemTest

I have built a number of SILICON CHIP projects over the past 10 years and managed to get them all to work. However, I've recently tackled the SemTest project from the February, March & May 2012 issues which has caused me some problems.

Although all of the key voltages test OK, including the supply to the PIC16F877A, I cannot get the startup display to appear. The LCD lights up and the dimming control operates, but no text.

I initially thought that the wiring (ribbon cable) from the micro to the LCD was at fault but all of these connections test OK.

The menu and test button connections to the micro are also correct and the switch short appears at the appropriate micro pins when each of the buttons is pressed. There is no response associated with pressing any of the buttons from either the LCD display or the test LED.

I would have expected the LCD screen to provide some sort of message provided both it and the micro are operating and properly connected, irrespective of any faults that might be present in other parts of the circuit.

This led me to think that either the PIC16F877A itself was faulty or the program was corrupted. The micro used was pre-programmed from the SILICON CHIP Online Shop. I obtained a second PIC16F877A from the Shop but this hasn't fixed the problem.

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I recognise that you probably can't give detailed assistance in troubleshooting this type of problem with individual projects.

However, it would be appreciated if you could verify that the batch of programmed PIC16F877As you have in stock for the SemTest project are all OK. I can then move on to look at other possible causes knowing that the micro is unlikely to be the problem. (K. B., Hobart, Tas)

● There have been one or two constructors of the SemTest unit who have reported much the same problem and as far as we're aware, their problems were all found to be caused by poor connections between the IDC connectors and the ribbon cables.

Not in the solder joints between the connectors and the PCBs but inside the crimped part of the connectors, where each fork at the rear of a contact hasn't made reliable contact with the wire inside the ribbon.

We don't believe there have been any problems caused by the PIC-16F877A micros purchased from the SILICON CHIP Shop. So we suggest you use a scope (if you have access to one) to check that all of the signals from the micro to the LCD are getting through.

The most important signals in this case are the RS and EN signals, which emerge from pins 9 and 8 of the micro and should be reaching pins 4 and 6 of the LCD. If either of these signals is not getting through, this would certainly result in no display.

These signals are sent to the LCD very soon after power up, to provide the initial greeting display. So it's fairly easy to monitor them at this time. We hope this helps you to track down the cause of your problem. SC

Next Month in Silicon Chip

Getting Started with the Micromite, Part Three

In the third part of Geoff Graham's MMBasic programming tutorial, he covers some more advanced subjects such as data types, arrays and drawing text on an LCD screen.

Industrial Robots

Dr David Maddison takes an in-depth look at the history of industrial robots. He describes some of the amazing devices being used today to assemble vehicles, build bridges and many other tasks with a speed and precision that humans can't match.

Micromite-based Direct Digital Synthesis

Using the Micromite LCD BackPack with a low-cost, pre-build DDS module to build a signal generator which can produce a variety of waveforms with an adjustable, precise frequency.

Automotive Electronic Fuse

Sick of having to replace blown fuses? This electronic fuse works like a standard fuse except that it can be reset by pressing a button. Its trip current is set by changing a resistor value. It gives your circuit the protection of a fuse without the hassle.

Note: these features are prepared or are in preparation for publication and barring unforeseen circumstances, will be in the next issue.

The April 2017 issue is due on sale in newsagents by Thursday March 23rd. Expect postal delivery of subscription copies in Australia between March 23rd and April 10th.

Notes & Errata

GPS-Synchronised Analog Clock Driver, February 2017: the CP2102-based USB/Serial interface requires inverted signalling compared to the PICAXE programming cable, so the latest version of the software includes four different HEX files; two for clocks with stepping hands, for use with a USB/serial cable (04120217A) or PICAXE cable (04120217B); and two for clocks with sweep second hands, for use with a USB/serial cable (04130217A) or PICAXE cable (04130217B). By default, programmed micros are supplied with the -A versions; if you require the alternative version, please indicate this clearly at the time of purchase.

Improved PICAXE Wireless Rain Alarm, Circuit Notebook, January 2017 (page 61): there are two errors in the circuit diagram published. A 10kΩ pull-up resistor was omitted between pins 4 and 1 of IC1. Also, the 0V rail of CON1 has no GND, leaving the filter capacitors isolated; they should be connected to 0V.

High Power DC Motor Speed Control, January-February 2017: on page 66 of the February issue, the PCB overlay (Fig.4, at top) incorrectly labelled LK8 as HSS when it should be LSS; however, note that it was correctly shown in blue (indicating it is fitted for low-side switching).

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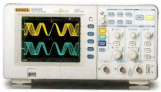

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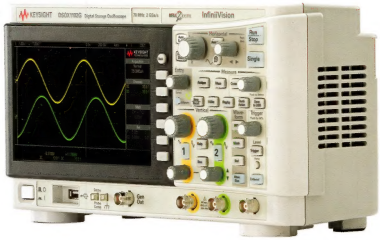

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